Representation, focus, and movement of covert visual attention

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Abstract

This thesis investigated some of the factors involved in the representation, focus, and movement of covert attention in visual space.

Existing research has shown that visual cues produced a facilitation of reaction times (RTs) to visual targets appearing at a cued location for up to 300ms. At longer stimulus-onset-asynchronies (SOAs), this was followed by an increase in RTs relative to the uncued location. This has been termed inhibition of return (IOR). Experiments 1-6 used LED cues which were the same as, or spatially distinct from, a target LED, and were either informative or uninformative about the target location. Results were inconsistent. Where discrimination problems existed, the cue/target probabilities altered the results: from evidence of inhibitory effects, to no significant cue-side effects. Where no discrimination problems existed, facilitatory effects were apparent, and were enhanced by an increased cue/target probability.

Experiments 7-10, using exogenous cueing, manipulated attentional focus and the presence of cue-markers. Altering the focus size did not substantiate previous findings of a reciprocal relationship between focus and performance. The removal of cue-markers resulted in increased amounts of inhibition not supporting current single- or dual-component views of IOR.

Previous work has shown that informative symbolic visual cues produced costs and benefits of RTs to visual targets. Experiments 11-16, using static endogenous cueing with targets framed in central and peripheral locations, attempted to demonstrate object-based attentional representation. All six experiments showed significant effects due to SOA and cue validity, however, initial results showed no evidence of stimulus-grouping. Only when target position markers were removed, when peripheral targets were used, and when inside/outside location judgements were required instead of target detection, did results indicate some possibility of grouped attentional representation.

Finally, several of the experiments also investigated the nature of attentional movement. Results did not support straightforward analogue explanations.

Dedication

Moim kochanym rodzicom

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Declaration

The work contained in this thesis has been carried out by the author in the Department of Psychology at the University of Durham. None of the material contained in this thesis has been submitted in candidature for any other degree.

Statement of copyright

Chapter 1
General Introduction

1.1 Historical perspectives and contexts

This thesis is concerned with the general topic of visual attention. It is a feature of human behaviour that everyone is familiar with and its study has a long history. Many locate the origins of empirical research with Helmholtz (1866) and with William James (1890) whose quote is now very familiar:

> "Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalisation, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others." (pp 403-404)

However, many of the primary attributes of attention touched on in the quote above were already recorded and discussed by the Greeks and Romans, and the main phenomenal descriptive aspects were formulated by the seventeenth century (see Table 1.1 below). The main theoretical positions were developed by the end of the 18th century: for example, "the view of attention as a selective mechanism; the analysis of attention in terms of processing resource allocation; and the distinction between automatic and attentional processing" (Hatfield, 1998, p17; also see Parasuranam & Davies, 1984). And the principal areas of experimentation were developed by the end of the 19th century.

These historical positions have set the contexts for current work on attention and this, just as in many areas of psychology, has tended to be disjointed: work on attention as a selective mechanism; early versus late selection; attention as allocation of processing resources; under voluntary or involuntary control; automatic versus attentional processing.

During and after the Second World War, research in attention focussed on the topic of selectivity at early (perceptual) stages or at late (response) stages of information processing. The interest and necessity (e.g. of pilots and radar operators) in dealing with and acting on multiple signals from multiple sources had motivated researchers to investigate the processes involved in detection and attention.

Table 1.1 A summary of the first mention of phenomenological descriptions of attention according to Neumann (1971) and Hatfield (1998)

	From Neumann	From Hatfield
Narrowing	Aristotle	Aristotle
Active directing	Lucretius	Lucretius
Involuntary shifts		Augustine of Hippo (AD354-430)
Clarity	Buridan (1518)	Aristotle/Lucretius
Fixation over time	Descartes (1596-1650)	Descartes
Effector sensitivity	Descartes	Lucretius
Motivational aspect	Leibnitz (1646-1716)	Augustine/Descartes

The experimental techniques at this time primarily involved audition though some visual tasks were being developed too using tachistoscopic presentation. (Notice that the emphasis at this time was on that of cognitive psychology and inner processes. Instruments for measuring external or other variables, such as eye movements, or brain functioning, were not yet readily available and the research and theory was inevitably driven by these technical and philosophical forces.)

Cherry's (1953) work on dichotic listening and Sperling's (1960) partial report experiments showed that participants could attend to information at one 'channel' (i.e. ear) and largely ignore information at the other channel. Broadbent (1958), a hugely influential researcher, suggested an 'early selection' model where a large-capacity temporary store held relatively unprocessed stimuli for a short time. This information was then filtered (the filter being a device with which to allocate attention) on the basis of physical characteristics, and identified or processed further. This attentional selection device was deemed necessary to stop the limited-capacity central processing system from being overloaded.

Later work demonstrated that some information at the 'unattended' channel was also processed (e.g. Moray (1959) showed that participants noticed their own name). This led to the development of late selection response stage models (e.g. Deutsch & Deutsch, 1963) where all stimuli were preattentively analysed, but only the most important signals were passed on to the response stage. Treisman (1964) however, suggested that information is not blocked from the unattended channel but is attenuated so that some important signals are allowed to travel through the filter. Others have proposed a moveable bottleneck depending on the circumstances (e.g. Norman, 1968; Johnston & Heinz, 1978) and indeed Broadbent himself (1982) said that filtering could be seen as a strategy to allow for good performance during times of interference. For example, in a 'noisy' situation a participant "who selects those events possessing a particular physical feature...will be able to cope adequately with those events at the cost of knowing less about the remainder of the things that are happening" (p259).

More recently with the development of computer technology and eye movement recording devices, work on attention has shifted to the visual domain and has focussed in on the issues of the organisation of visual space and concomitant costs and benefits produced by selecting areas of space, or perhaps objects, for greater processing.

1.2 Methodology

(Posner's methodology – Endogenous/exogenous cueing – Inhibition of return)

The methodology used in this thesis comes primarily from the work of Posner and his colleagues, so some time will be spent describing their findings and other issues related to their techniques.

Helmholtz (1866) carried out experiments which seem to be the starting point of the cost-benefit analysis. He reported studies where letters were briefly illuminated, and with ocular fixation maintained and eye movements 'prevented', he claimed that it was possible for visual attention to be focussed voluntarily on any part of the display. Such attended parts of the visual field were perceptually enhanced in comparison to those areas which were not attended.

This separation of attention and fixation was a remarkable and noteworthy experimental finding and perhaps led Posner (1980) to distinguish "between overt changes in orienting (the aligning of attention with a source of sensory input) that can be observed in head and eye movements, and the purely covert orienting that may be achieved by the central mechanism alone" (p5) and to research the question of whether processing is indeed more efficient when prior warning of a target location has been given and a shift of attention has been made.

Posner and Petersen (1990) divided the attentional system into three subsystems: an orienting component, a detection component, and a vigilance component. Visual orienting, akin to Helmholtz's attention focus, involves aligning of peripheral or central mechanisms with a spatial location or structure stored in memory, for more detailed analysis at the expense of other items. Detection enables more conscious analysis of a signal as well as of information stored in memory – it indicates that a stimulus has reached a level (of the nervous system) where its presence can be reported. Vigilance can be described as the overall activation level of the central processing system; it is important in keeping alert and affects the rate that attention can react to a signal.

It is the first of these components in its covert form that will be the main concern of this section and indeed of this thesis.

Posner and his colleagues carried out numerous experiments investigating the nature of the covert orienting component and developed the methodology that will be used in this thesis. For example, Posner, Nissen and Ogden (1978) asked participants to fixate a central location. Following a certain interval, an arrow cue, indicating the direction of a possible target, replaced the fixation. Participants were required to covertly (that is without moving their eyes) redirect their attention in the direction of the arrow and press a key at the appearance of a target. Manual reaction times were speeded to targets appearing at the cued location. These were called valid trials and occurred on the majority of occasions. Reaction times (RTs) were slowed to targets appearing in the uncued location. These minority trials were called invalid. The benefits (decreases in RTs) and costs (increases in RTs) were defined with respect to a 'neutral' no arrow condition and explained in terms of a facilitatory effect of visual attention at the cued location, and the time taken for an attentional movement to the uncued location.

Posner, Walker, Friedrich and Rafal (1984) divided orienting into three processes saying that attention is engaged, disengaged and moved. Thus, initially, when attention is being paid to a location it is engaged; in order to shift to a new location attention must first be disengaged from the current point and only then moved. Each of these processes is assumed to take time and accounts for the costs and benefits accrued during the cueing experiments. The benefits obtained in the valid trials are due to the prior disengagement and movement of attention to the cued location. The costs reflect the additional time taken to disengage and move attention from the cued location and engage at the target location.

Evidence for these three processes came from work with patients: damage to the thalamus causes problems with attentional engagement (Rafal & Posner, 1987); damage to the parietal lobe causes problems of disengagement (Posner, Walker, Friedrick, & Rafal, 1984); and damage to the midbrain results in difficulties with attentional movement (Posner, Rafal, Choate, & Vaughan, 1985).

In the Posner, Nissen and Ogden (1978) experiment described above, a symbolic cueing procedure was used. This symbolic cueing can be contrasted with experiments using peripheral cues. For example, Posner and Cohen (1984) presented a central fixation box with two peripheral boxes 8^0 to the left and to the right. Trials involved a 150 ms brightening of one of the peripheral boxes (a cue) followed at various intervals by a probe (or target) which was most likely to occur in the centre box (p=0.6), but then equally likely to appear in one of the side boxes (p=0.1). A facilitation of RTs to the target probe was found when the peripheral cue coincided with the target location up to a cue-target onset interval (SOA) of about 300 ms. And, following this, at later SOAs, a detection time cost was found such that RTs were faster to targets at the uncued, rather than at the cued, location. (This latter finding is known as Inhibition of Return (IOR) and will be discussed in a little more detail later in this section.)

Even when these peripheral cues carry no real spatial information about the likely location of a target (i.e. when the probability of the cue and target occurring on the same side or opposite sides is 0.5) they still produce facilitatory and inhibitory effects. Moreover, it seems that attention is automatically drawn to the peripherally cued locations even when participants are instructed, or attempt, not to shift their attention. For example, Jonides (1981) presented targets with a spatially non-predictive preceding cue. One group of participants were told explicitly to attend to the cued location, whereas a second group were explicitly told to ignore the cue since it provided no useful locational information. Despite these instructions both groups showed the facilitatory effects of the peripheral cues.

(Incidentally, Jonides compared peripheral and symbolic cueing in his experiment, and found that the instructions to participants did affect the outcome of the latter form of cueing: the symbolic cues were only effective when participants were instructed to attend to them.)

Remington, Johnston, and Yantis (1992) tested this instructional finding further. They compared a number of conditions: where the cue always indicated the location of the target; where the 'cue' never indicated the target location, so participants were urged to actively suppress the cue if at all possible; as well as conditions where all locations were cued, and none of the locations were cued. They confirmed Jonides' finding that participants were unable to ignore the cue.

One study, however, has managed to alter this pattern of results. Warner, Juola, and Koshino (1990) asked participants to practice a cued letter identification task. Although initially results matched those of earlier studies, following a great number of trials (4500) participants were eventually able to orient attention to the location opposite to that of the cue.

Despite the apparent similarities between the two types of cueing procedure, a number of results have led researchers to suspect that they operate on two different sub-systems, forming part of a single attentional orienting system. Higher level cognitive processing is required to interpret central symbolic cues (e.g. arrows or letters) and voluntarily move attention to the desired location. In contrast, as just discussed above, peripheral cueing by a sensory event, (e.g. a flash) automatically draws attention to the cued location. The attentional sub-system used to control voluntary movements under the control of central cognitive processes and arising from a symbolic cue has been termed voluntary (Müller & Rabbitt, 1989), endogenous (Posner, 1980), and sustained (Nakayama & Mackeben, 1989). The sub-system used for automatic attention shifts not under cognitive control has been called reflexive (Müller & Rabbitt, 1989), exogenous (Posner, 1980), and transient (Nakayama & Mackeben, 1989).

The evidence for these two components comes from a variety of sources: experiments involving secondary tasks; time course differences; the effects of uninformative cues; double-cueing; the neural bases of attention; and inhibition of return.

Jonides (1981) carried out an experiment which involved a secondary memory load in addition to an attentional cueing task. He found that whilst participants' results were unaltered during peripheral cueing if given this secondary task, during symbolic cueing voluntary covert orienting had been affected. He suggested that because both symbolic cueing and the memory task require central cognitive control, the two would compete with each other. A peripheral cue, which automatically attracts attention to a location, however, would not draw on the same resources as the memory task and hence not be affected by it. He concluded that this result provided evidence for two modes of a single orienting system.

Müller and Findlay (1987) and Müller and Rabbitt (1989) have provided a different insight into the two component view. An examination of the time course for the two cueing techniques resulted in different cost/benefit effects. Peripheral cues produced rapid orienting with the fastest RTs when the cue onset was between 100-300 ms before the target and a peak at 175 ms. Performance decreased slowly up to 400 ms SOA and then remained stable. The symbolic cues produced gradually increasing benefits up to about 300-400 ms SOA with longer lasting effects than peripheral cues.

As mentioned earlier (see Jonides (1981) above), exogenous peripheral cues carrying no real information about the likely location of a target still produce facilitatory and inhibitory effects, whilst endogenous symbolic uninformative cues (i.e. those indicating a probability of 0.5 of the target occurring in the cued direction) result in no benefits or costs.

In their dual cueing experiments, Müller and Rabbitt (1989) used peripheral and symbolic cues acting compatibly and in opposition. Participants were asked to judge whether a target was the same as or different to another stimulus and to specify the target and cued positions. The experimenters measured the participant's probability of a correct judgement and a correct position response at various SOAs. When peripheral and symbolic cues were compatible, the benefits were larger than when the cues were incompatible. When peripheral and symbolic cues were placed in opposition, for example, when attention had been oriented to a cued location by a central symbolic cue and a second irrelevant peripheral flash cue occurred, performance was greatly reduced. However, invalid peripheral cues produced greater costs in performance than did invalid symbolic cues.

On the basis of these results Müller and Findlay (1987) and Müller and Rabbitt (1989) (and others, e.g. Cheal & Lyon, 1991; Nakayama & Mackeben, 1989) have argued not for a 2 sub-component system as suggested by Posner, but for two separate orienting mechanisms: one fast-acting, responsive to peripheral stimuli, drawing attention rapidly and automatically, and then fading rapidly; and a second, which is slower-acting, requiring effort by cognitive control, and is voluntary. Final performance is thought to be determined by a combination of both these orienting mechanisms.

Researchers additionally propose that these two attentional mechanisms may have different underlying neural bases, a suggestion supported by earlier work by Posner and Cohen (1984). These workers argue that exogenous attention shifts are linked to the saccadic system brain mechanisms, whilst endogenous orienting is linked to spatial orienting control systems such as the parietal areas.

Since it is important in later discussions, one final characteristic of the cueing paradigm will be emphasised here: as already described, following a valid stimulus both exogenous and endogenous cueing result in facilitation, or benefits of RTs to targets, usually followed by a subsequent reduction in performance. (This reduction in performance may of may not occur with endogenous cueing since attention can be held at the cued location for some seconds.) The automatic slowing down of target detection following longer SOAs using exogenous cues has been termed inhibition of return (IOR). Although not all workers have demonstrated this effect (e.g. in visual search, Klein & Taylor, 1994; Wolfe & Pokorny, 1990), many others have shown IOR using a variety of experimental procedures: temporal order judgements (Gibson & Egeth, 1994); discrimination tasks (Pratt, 1995); repeated colour target detection (Law, Pratt, & Abrams, 1995); cued eye movement studies (e.g. Abrams & Dobkin, 1994); auditory target detection (Reuter-Lorenz, Jha, & Rosenquist, 1996); as well as visual attentional cueing (e.g. Maylor, 1985; Tipper, Weaver, Jerreat, & Burak, 1994; McAuliffe, Pratt, & O'Donnell, 2001).

Researchers suggest that IOR reflects a bias against previously attended spatial locations, or a bias that favours novelty, or new objects. One of the main purposes of this inhibitory effect would presumably be to enable efficient search (Klein, 1988, 2000). Once attention had been directed to a location, it is inhibited to prevent return for a certain period – no need to attend there again until the search is terminated. However, as mentioned earlier, the IOR effect has not always been successfully linked to visual search. If IOR is attributed to an attentional mechanism then what is it that causes the effect? Since IOR can be a long-lasting effect - found at SOAs of more than one second (Maylor, 1985; Rafal, Calabresi, Brennan, & Sciolto, 1989) it cannot be accounted for by forward masking which fades after about 100 ms. Nor can it be accounted for by any simple neural processes since it is not tied to the location of retinal stimulation (see later description of Tipper, Driver, & Weaver (1991) who demonstrate object-based IOR). One account that does seem to fare relatively well, relates IOR to the oculomotor system. If endogenous and exogenous cueing are similar to each other, and IOR is only indirectly related to orienting, then it is possible that it could be related to the eye movement system. (If endogenous and exogenous cueing are different from one another then this would simply explain why IOR only occurs with exogenous and not endogenous orienting, and there would be no need to call on a different system.) Rafal, Calabresi, Brennan, and Sciolto (1989) suggest that IOR is not a direct result of exogenous cueing. Instead they propose that such cues cause an automatic activation of the oculomotor system, programming an eye movement to the cued location. They found that not only did IOR occur when an eye movement occurred, but IOR was also present when a saccade was planned, but not made. However, not all tasks showing IOR are best described by the oculomotor hypothesis (e.g. Law, Pratt, & Abrams, 1995; Abrams & Dobkin, 1994; Hunt & Kingstone, 2003).

1.3 Location-based versus object-based accounts of attention

One of the most important questions asked about attention in the last 20 years could be said to be that asked by Kahneman and Henik in 1981: “If attention selects a stimulus, what is the stimulus that it selects?” (p183). Up until then, views of attention were mainly location- or space- based accounts. Following Kahneman and Henik, however, the possibility that attention could be allocated to objects or perceptual groupings began to be considered. This next section presents a summary and analysis of a number of location-based accounts (the spotlight metaphor, zoom-lens, gradients of attention and hemifield inhibition), followed by the evidence for an alternative viewpoint, that of object-based attentional orienting. The literature in this area is extensive and this review is not intended to be exhaustive, but to highlight the most important findings and most relevant studies to this thesis.

1.3.1 Attentional spotlight

(Analogue vs quantal movement? Beam size fixed or variable? Problems with the account)

The most dominant metaphor for describing covert visual attention was coined by Posner and his colleagues (Posner, Snyder, & Davidson, 1980), although the idea of a narrowed attentional field may have already been discussed by the Greeks (see earlier section on Historical Perspectives.). Posner envisaged that attention acts as a 'spotlight' which moves across space, enhances the portions illuminated with the result of improved processing of stimuli, to the detriment of those areas and stimuli left in the dark. The spotlight description initially received much support. For example, as mentioned earlier, the ideas of engagement, disengagement and movement, were highlighted by studies of neurologically damaged patients. Work in visual search incorporated the notion of a spotlight into Treisman's very influential Feature Integration Theory (Treisman & Gelade, 1980; Treisman, 1988, 1993). Many other experiments were conducted apparently confirming the notion of a fixed size unsplittable beam with analogue movement.

For example, Shulman, Remington, and McLean (1979) carried out an experiment using near and far locations with valid and invalid trials. They claimed that their findings supported the notion of a moving spotlight since at short SOAs there was an advantage for targets appearing at the near location, whereas for longer SOAs this was reduced. Their interpretation was that at short SOAs attention had moved to the near location with the resultant fast RTs, whereas at longer SOAs attention had passed through to the more distant expected target location at 18^0 eccentricity. Tsal (1983) agreed that moving the spotlight took time and theorised that if it moves in an analogue fashion then after a certain time it will have moved to the cued location and performance would reach an asymptote. Using five SOAs and three eccentricities he estimated the analogue movement of attention as a rate of 1^0 per 8 ms.

Eriksen and Eriksen (1974) proposed a spotlight of fixed size. They suggested that stimuli in a certain area would be advantaged by attention, with no special focus on individual items. In their experiment, participants were presented with target letters along with flanking distractor letters. Distractors were either of the same response category or opposite response category and presented close to the target (within 1^0) or further away (more than 1^0). RTs were slowest in conditions with distractors of the opposite response category but only if the distractors were close to the target. Eriksen and Eriksen therefore concluded that the spotlight beam was of a fixed size of about 1^0.

Eriksen and Yeh (1985) addressed the issue of a splittable spotlight. Their experiment involved cueing participants to 4 locations on a clock face and varying the validity of the cue to a primary target location and an opposite location. Results showed RTs were fastest at the primary cue location, next fastest, but much slower, to the opposite location, and slowest to the non-cued locations. They concluded that participants could not split the spotlight and the 'opposite location' finding was a consequence of participants moving the spotlight to the secondary location after having first attended to the cued location

These results and many others initially seemed to indicate that the spotlight metaphor was a convenient and useful way of describing movements of attention and a reasonable means of accounting for the increasing number of results produced by workers in this area. However, popular as it was, other work began to undermine the notion of a spotlight and questioned the analogue movement of this fixed size unsplittable beam.

For example, Humphreys and Bruce (1989) looking more closely at the Shulman, Remington, and McLean (1979) data found that in fact their results were not consistent with the ideas of a moving spotlight. Humphreys and Bruce noted that at SOAs of 200 ms the RTs to targets occurring at near cued locations were fastest and those at far expected locations were relatively slower. Shulman et al's explanation for this was that at 200ms following the cue, participants would be attending to the cued near location and en route to the far expected location. This would be compatible with the notion of a fixed size moving spotlight were it not for an additional finding: at SOAs of 200 ms RTs to targets to near unexpected locations (i.e. those to targets on the side opposite to the direction of the movement) were equal to those to far expected targets. If the attentional spotlight is supposedly moving away from this unexpected location towards the expected side, it is difficult to explain these equal RTs. Also, Yantis (1988) criticised Tsal's study since it did not control for factors of general arousal or alertness. He stated that both Tsal's and Shulman et al.'s experiments were "simply inconclusive about whether attention shifts have continuous or discrete dynamics" (p205).

For example, Humphreys and Bruce (1989) looking more closely at the Shulman, Remington, and McLean (1979) data found that in fact their results were not consistent with the ideas of a moving spotlight. They noted that at SOAs of 200 ms the RTs to targets at near cued locations were fastest, however those for far expected locations were equal to those at near unexpected locations (i.e. on the side opposite to the direction of the movement!). It is difficult, therefore, to see how such a result could be obtained with a moving spotlight of fixed size. Also, Yantis (1988) criticised Tsal's study since it did not control for factors of general arousal or alertness. He stated that both Tsal's and Shulman et al.'s experiments were "simply inconclusive about whether attention shifts have continuous or discrete dynamics" (p205).

Other researchers have shown evidence in favour of distance-independent quantal movements of attention. For example, Sagi and Julesz (1985) asked participants to judge whether simultaneously presented rotated T's and L's at various distances from each other were the same or different. The results indicated that accuracy was independent of distance irrespective of stimulus-mask onset. This led them to conclude that shifts of attention were "fast" and "noninertial" (p141). Similarly, Kwak, Dagenbach, and Egeth (1991) using identical stimuli, but this time positioned in a circle to control for acuity also found distance-independent performance. And, more recently, Chastain (1992) and Sperling and Weichselgartner (1995) indicated that not only was the movement of attention uncorrelated with distance, but that attention could jump over irrelevant stimuli and locations in the display without adding any additional time.

Despite continued disagreement about whether attention is allocated to intervening stimuli and locations, the balance of evidence seems to imply that it is not; that attention is engaged to new locations simultaneously as it is disengaged from old positions. Work on the physiology of attention suggests that this could be achieved by an increase in activity of a group of neurons whose receptive fields covered the to-be-attended position with a simultaneous decrease in activity for those neurons whose receptive fields covered the old location. (Motter, 1994; Schall, Hanes, Thompson, & King, 1995.)

The notion of a fixed size unsplittable spotlight was also questioned. The nature of visual stimuli is such that they vary along a number of dimensions (e.g. in size; in shape). It seemed plausible to suggest then that the attentional spotlight should also vary to accommodate this variability. The next section looks at the development from the spotlight to the related concept of a zoom lens.

1.3.2 Zoom lens

(Can the attentional beam size be adjusted? What are the effects of varying focus? Are there gradients of attention?)

Although the spotlight metaphor was an appealing one, an alternative analogy, that of the 'zoom lens' seemed to fit in with an increasing number of findings. Evidence for the zoom lens came initially from Eriksen and St.James (1986) who asked three questions about the attentional focus: firstly, can its spatial extent vary?; secondly, does processing efficiency decrease with increasing area of focus?; and thirdly, is the focus boundary a sharp cut-off or is there a spatial gradient?

In their experiment, Eriksen and St.James (1986) asked participants, following an underlining letter precue, to discriminate between two target letters presented amidst a circular array of seven distractor letters. A number of important variables were altered: the timing of the cue and display; the number of cued adjacent locations; and, the presence and distance of compatible or incompatible distractor letters. It was predicted that the attentional zoom lens would initially be set to a wide range to encompass the whole display and would then, dependent on the number of precues, be reduced to a smaller field of view - the smaller the number of precues, the smaller the field of view. It was also expected that incompatible distractors two or three positions away from the target would cause greater interference at short SOAs (when the zoom lens was widely set) than at long SOAs (when the beam was narrowed).

The results fully supported the notion of a flexible zoom lens: performance improved with increasing SOA - consistent with the idea of field of view narrowing with time focussing the finite resources onto a smaller beam area and improving processing capability; as the number of cued locations increased, increasing the attentional field, so did RT – as a result of decreased attentional resources; worst performance was for incompatible letters one position from the target and performance improvements with time were greater for distractors three positions away from the target than those for two or one position away – again this is consistent with the notion of a narrowing beam, such that more distant distractors have less effect.

The account of their data seems plausible, and moreover such a zoom lens description can also encompass earlier data. For example Tsal's (1983) and Shulman et al.'s (1979) results can both be explained by the time needed to focus the attentional beam from an initially broad field to a narrower view rather than the time taken to move an attentional spotlight.

Apart from Eriksen and his co-workers, there have been relatively few researchers that have attempted to answer the three questions posed (i.e. can the spatial extent of attention vary? does processing efficiency decrease with increasing area of focus? and is the focus boundary a sharp cut-off or is there a spatial gradient?):

Egeth (1977) presented large and small areas where targets could appear. He found that responding was faster for targets in the small area. La Berge (1983) and LaBerge and Brown (1986) tried to assess the shape of the attentional focus. Participants were asked to identify whether five-letter strings were a male name or not, or whether the middle letter of the five was a consonant or a vowel. Additionally participants were asked to respond as quickly as possible to a probe dot which sometimes followed the letter string. The first task was intended to produce either a large or a small attentional focus and the second task was used to map the effect on responding. RTs for the letter identification task were fastest for the middle position whereas RTs for the word task did not vary as a function of the probe location. On the basis of these results LaBerge concluded that the size of the attentional focus could vary as a function of the task demands and that the processing efficiency would vary in response to the focus size. However, unexpectedly, in the earlier study (LaBerge, 1983), it was found that RTs were faster when the focus of attention was wider (i.e. with the word task); but this result was not confirmed by the later LaBerge and Brown (1986) study.

Larsen and Bundesen (1978) and Cave and Kosslyn (1989) varied the size of the stimulus that participants were expecting. They found that response times increased as the ratio between the actual size and expected size increased indicating that participants can prepare themselves for a particular focus size, but the more the stimulus deviates from this size, the more time it takes them to process or identify it.

Castiello and Umiltá (1990; 1992) used a Posner box cueing task to address the size of focus and efficiency of processing question. They presented participants with two boxes either side of a central fixation and asked them to respond to targets occurring within the boxes following a cue. The box sizes were either 1^0, 2^0, or 3^0 square. They found that the size of the attentional focus was adjusted to cover different sized stimulus areas; that the efficiency of processing (measured in terms of RT benefits) decreased with increasing area of attentional focus; and that processing efficiency gradually dropped off around the attentional focus. (This result was further supported more recently by Maringelli and Umiltá (1998)).

One can clearly see here the importance of a narrowed more focussed attentional beam, but what might be the purpose of increasing the size and having a varying sized lens? One answer comes from Humphreys and Bruce's (1989) ideas of spatial scale:

"Broad distribution of attention may be important for initial scene processing and segmentation...Narrow distribution of attention may be important for fine discriminations and the identification of individual objects. The world we view is naturally composed of structures at different spatial scales. At a course level we may see a forest near a lake, at a somewhat finer level we see the trees that make up the forest, and more finely still we may see the individual leaves of the tree. The zoom lens metaphor for visual attention would capture the way we chose to see either a forest or leaves at different times." (p149)

Before leaving the spotlight and zoom lens metaphors, I would like to mention two further issues relating to the form of the attentional spotlight perhaps falling somewhere between the two metaphors and already suggested by some of the studies looking at attentional focus – the gradient of attention and the hemifield inhibition model.

Downing and Pinker (1985) presented a symbolic number cue (1 to 10) to participants whose task was to react to a target in one of ten possible locations from far left to far right. The results indicated that for cued locations near the fovea/fixation RT performance costs to targets appearing at the non-cued locations increased rapidly the further they fell from the cued locations. However, for more peripheral cue locations, costs to targets appearing at the non-cued locations increased gradually with distance from cue location. This supports the possibility of an attentional spotlight that may be of a variably fixed size! That is it is fixed for particular regions of the visual field, but that this size varies from region to region: narrowly focussed in the fovea and broadly focussed in peripheral vision.

This notion of a gradient of attention is supported by the findings of Castiello and Umiltá (1990; 1992) mentioned above and by those of Usai, Umiltá, and Nicoletti (1995). They used endogenous cueing techniques and showed that attention formed a unitary zone that may vary in size to include relevant stimuli, but must also include the area between these locations. They also concluded that there was a gradient of attention within the focus and a symmetrical and more gradual fall-off outside the attentional focus.

Further support comes form Henderson (1991; Henderson & Macquistan, 1993) who showed that attentional gradients may be adjusted according to the task. If participants are given a precise locational cue about a target, the distribution of attention has a high peak and a steep gradient. If participants are given a less informative cue, the distribution of attention shows a lower peak and a flatter gradient.

These gradations of effects and benefits for directing attention to a cued location have not been found by all researchers. Hughes and Zimba (1985, 1987), found that when the cue and the target were in the same hemifield, RTs were uniformly fast. However, when cue and target were in opposite hemifields RTs were uniformly slow. This led to the development of a different proposal: the 'hemifield inhibition model' also occasionally called the 'hemifield activation hypothesis' (Klein & McCormick, 1989).

Rizzolatti, Riggio, Dascola, and Umiltá (1987), like Downing and Pinker (1985), did find distance effects (i.e. slower responding) within a visual quadrant, but also, like Hughes and Zimba (1985, 1987) found costs when the cue and target appeared in different hemifields.

One of the important differences between these studies (and incidentally between studies looking at attention to locations in 3D space e.g. Downing & Pinker, 1985; Gawryszewski, Riggio, Rizzolatti, & Umiltá, 1987; Ghirardelli & Folk, 1996; Iavecchia & Folk, 1994) is the amount of 'structure' in the display. Downing and Pinker, and Rizzolatti et al. used target position markers (sometimes referred to as landmarks or placeholders) whereas Hughes and Zimba presented stimuli on a relatively empty screen. Moreover, Hoffman and Mueller (1994; cited in Yantis, 1998) note that it is critical whether or not there are well-defined objects to which attention can be oriented. When Zimba and Hughes (1987) used target markers they too found distance effects.

1.3.3 Object-based accounts

Whilst many researchers have adopted a spatial approach to attention, a number of workers have considered the possibility that selection might also be on the basis of perceptual objects. Our retinal image only provides a disjointed and patchy representation of visual space, yet our perception is of a world which makes sense and is filled with coherent objects. It seems plausible to suggest therefore that attention might be directed to objects grouped together according to Gestalt principles. Kahneman and Henik, as early as 1981, suggested that it is indeed these perceptually organised objects that might form the representational basis for selection.

Most of the evidence in support of object-based attention falls into two categories: divided visual attention studies where the location or features of stimuli are investigated in relation to their object structure or spatial grouping; or studies where attention is directed to moving objects. Both of these approaches attempt to separate out, or eliminate, effects due to attentional allocation given to spatial locations in order to demonstrate that results are due to attention given to locationally invariant object representations. The majority of the studies outlined below have used exogenous cueing. Very few have attempted to show object-based effects using endogenous cueing.

Rock and Guttman (1981) carried out one of the first experiments on attentional grouping. Following an aesthetic judgement task engineered to orient participants to green or red objects, participants were given an object recognition test. Attended objects were more frequently reported as old items and unattended as new items. The result inferred that attention may not be simply spatially-based but based on the physical features of objects.

Duncan (1984) suggested a three-way classification of attention theories: space-based theories (where selection is based on spatial coordinates); discrimination-based theories (where selection is limited to a number of discriminations); and object-based (where selection is based on objects). To test his ideas, Duncan asked participants to remember two attributes of a simple briefly flashed display consisting of a rectangle with a tilted line through the middle. The rectangle was either large or small with a gap in its left or right side. The line was tilted to the right or left and could be dotted or dashed. If the attributes to be recalled belonged to the same object (e.g. rectangle or line) then responses were more accurate than if the attributes belonged to different objects (i.e. one from the rectangle and one from the line). Since the rectangle and line occupied the same portion of space and the attributes of each object were equidistant, the results were taken as evidence to support object-based attentional selection.

However, these findings have been criticised on the basis that results could have reflected attending to the different spatial frequencies of the line (high spatial frequency) and the box (low spatial frequency) (Baylis & Driver, 1993; Watt, 1988). Also, Posner (footnote 1 in Duncan, 1984) suggested that the two objects might have been perceived as separated in depth. And, although the box and line were in the same portion of space, they were not in identical locations. The findings could therefore potentially still be accounted for by space-based accounts of attention.

Baylis and Driver (1993) used an ambiguous figure (Rubin's face-vase, 1921) and manipulated participants' set in an attempt to compare one- and two-object judgements for identical displays. Participants found comparing the two critical edges in the display more difficult when they had been set as part of two different objects (the face interpretation) than when they had been set as part of a single object (the vase). Since the stimulus used was in a single location, the results could be attributed to object-based attention. However, Baylis and Driver themselves commented that the results may have been due to figure-ground segmentation on edge assignment.

Vecera and Farah (1994) were also initially critical of Duncan's findings suggesting that their results may reflect a grouped location-based representation rather than object-based representations. Vecera and Farah presented the same objects used by Duncan either superimposed or separated. A location-based account would predict that the size of the object effect benefits should be greater for the separated condition than for the superimposed condition. (Note that this argument depends on the assumption that moving larger distances will cost time – a finding that, as discussed earlier, remains unresolved.) Vecera and Farah were surprised to find no evidence of different sized benefits and concluded that Duncan's results were as a consequence of visual selection from spatially invariant object representations. However, when they used a cued task which required participants to detect a small dot and which did not require a judgement related to the shape of the objects, Vecera and Farah found results that were consistent with location-based effects. They concluded that there may not be a single attentional mechanism but that attentional representations may depend on the task requirements: simple detection may yield location-based effects, whereas shape discrimination may require object-based representations.

Egly, Driver, and Rafal (1994) presented participants with two vertically (or horizontally) parallel rectangles. On 75% of trials (valid trials), following a cue (a brightening of one of the ends of one of the rectangles), a target to which participants were asked to respond, appeared within the cued location. On the remaining trials (invalid trials) the target either appeared at the other end of the same rectangle (same object target), or at the 'near' end of the other rectangle (different object target). RTs to valid trials were faster than those to invalid trials indicating a space-based effect. However, same object targets were detected faster than different object targets indicating an object-based effect. Many subsequent studies using adaptations of this procedure have found similar results (e.g. Atchley & Kramer, 2001; Behrmann, Zemel, & Mozer, 1998; Chen, 2000; Lamy & Egeth, 2002; Yantis & Moore, 1995; Yantis & Vaughan, 1998).

The second category of evidence in support of object-based attention comes from studies separating objects from locations using motion.

Driver and Baylis (1989) used grouping by motion to question both the spotlight and zoom lens accounts (e.g. Eriksen & Eriksen, 1974; Eriksen & St.James, 1986). Participants were required to respond to a moving letter. Two far distractors were moved congruently with the target letter, whilst two near distractors remained stationary. As in the Eriksen and Eriksen (1974) study, distractors were either of the same response category or of opposite response category to the target letter with the opposite/incongruent distractors producing the greatest disruption of performance. According to the spotlight and zoom lens views of attention, the near unmoving incongruent distractors should produce the greatest increase in RTs to targets since they fall within the focussed zone. The object-based grouping account would predict that the moving far incongruent distractors would produce the greatest interference since they are grouped with the target letter by motion. The results supported the idea that attention can be assigned on the basis of object/feature grouping rather than as a result of spatial proximity.

Kahneman, Treisman, and Gibbs (1992) presented participants with two shapes within which two letters briefly appeared. The shapes were then moved to a new location and a target letter that participants were asked to name appeared in one of the shapes. There were three possible trial types: if, for example, the original letter was a V presented in a triangle, on a same-object trial the target letter would be a V presented in a triangle; on a different-object trial, the target letter would be a V presented in a square; and on a no-match trial the target would be, say, an S presented in either shape. They found significantly faster naming times for same-object trials than for different-object trials; and no-match trials produced the slowest naming times. They interpreted their findings as showing a form of object-specific (p)re-viewing where object files, or temporary episodic representations of visual objects, are created and re-accessed.

Yantis (1992) used a multiple object tracking procedure developed by Pylyshyn and Storm (1988) where participants were asked to follow a subset of moving stimuli from a set of 10. After 7 seconds one of the 10 stimuli was flashed and participants were asked to judge whether this had been one of the tracked subset or not. Pylyshyn (1989) had suggested that participants were able to do the task by independently indexing each of the subset. Yantis however, suggested that an object representation (a virtual polygon) similar to Kahneman et al.'s object file could be created and indeed showed that performance was related to the ease with which such a perceptual grouping could be created.

Tipper and his colleagues have used the phenomenon of inhibition of return (IOR) to demonstrate object-based effects. Tipper, Driver, and Weaver (1991) presented two squares on either side of a central point on which participants were asked to fixate. The squares were rotated around an imaginary circle centred on the fixation point and, following a variable interval, one of the squares was brightened (a cue). The squares continued to rotate until they reached the opposite location (i.e. rotated by 180^0) when a target dot appeared in one of the squares. RTs to targets were faster when the targets appeared within a previously cued square than when they appeared at previously cued locations. Tipper et al. concluded that in these circumstances IOR is object-based. In 1994, Tipper, Weaver, Jerreat, and Burak extended this finding using four squares which were rotated through 90^0. On the basis of these results, they suggested that IOR has both an object-based and a location-based component. Furthermore, Tipper and his colleagues (e.g. Jordan & Tipper, 1998; Tipper & Weaver, 1998; Weaver, Lupiáñez, & Watson, 1998) suggested that these inhibitory effects were additive and that this additivity would account for the differences in IOR arising from static and dynamic displays.

1.3.4 Objects and locations?

The majority of the above discussions have contrasted object-based with location-based forms of attentional representation. However, it seems clear, and indeed there is a growing consensus, that attention may well be location-based in some contexts, object-based or object-part based in others (e.g. Vecera, Behrmann, & McGoldrick, 2000; Singh & Scholl, 2000), or even both at the same time (as in the Tipper, Weaver, Jerreat, and Burak experiment just described above). This conclusion has brought about a growing alteration in the direction of research, leading investigators to look for the conditions under which object-based and location-based attention operate and the nature of their coexistence and interaction.

One of the potential mediators distinguishing between the space-based and object-based attention is that of the mode of attentional cueing. Exogenous cues have typically been reported as inducing object-based attention and endogenous cues eliciting space-based attention. If this is indeed the case then it would have important implications for any theoretical modelling of attention. For example, are there two mechanisms responding to the two forms of cueing, or a single common attentional system?

The majority of studies looking at object-based attention have used exogenous cueing of one form or another. Only a few researchers have attempted to demonstrate object-based representations specifically using endogenous cueing and the majority of these have met with failure, perhaps reinforcing the idea that only exogenous cues can elicit object-based representations.

For example, Macquistan (1997) altered the double rectangle cueing paradigm of Egly, Driver and Rafal (1994) to compare the two types of cueing. Using a spatially non predictive peripheral exogenous cue he found a significant object-based effect. However, using a centrally presented spatially predictive symbolic cue-arrow (i.e. valid trials were set at 75% cue-target predictability) he found no such object-based effect.

Abrams and Law (2000), again using a similar experimental paradigm to that of Egly, Driver and Rafal (1994), used endogenous cues to direct participants' attention to one end of a rectangle. The task was one of simple detection of a target appearing in either the cued location, a location within the same object, or a location in the other rectangle. Their results showed a same-object advantage (i.e. unattended locations in the cued object were advantaged over locations not in the cued object). On the basis of this evidence, as well as evidence from their temporal order judgment experiment, and a further study directing participants to make feature discrimination responses, they concluded that endogenous attentional orienting could be object-based.

In a partial replication of Lavie and Driver's (1996) line crossing experiment, Law and Abrams (2002) used central symbolic endogenous cues to direct attention to particular parts of crossed bars. Participants were asked to judge the relative size of two notches. The results again showed an object advantage although this did disappear when they shortened the stimulus duration.

Goldsmith and Yeari (2003) presented a number of experiments again using a methodology based on Egly, Driver and Rafal's (1994) double-rectangle display. They manipulated the spread of attention so that it was widely or narrowly distributed over the rectangles in the display. They concluded that object-based effects were evident for both exogenous and endogenous cueing when attention was spread, but that when attention was more focused these effects were reduced.

1.4 Outline of the thesis

The aim of this thesis was to investigate some of the factors involved in the representation, focus, and movement of covert attention in visual space. A number of issues in the attentional literature were addressed in the General Introduction and are returned to during the following chapters:

- Object- vs. space-based representations – Many studies have shown object-based effects using exogenous cueing, but only a handful have shown this property using endogenous cueing, and those that have, have used very similar techniques. Another methodology was attempted here. If such a further approach could show object-based findings, it would lend support to the notion of an integrated mechanism incorporating the space-object and endogenous-exogenous dimensions rather than a system that views these as independent.

- Inhibition of return – The phenomenon of inhibition of return has been found in many experiments looking at attentional orienting. The question specifically dealt with in this thesis was that of whether IOR consists of a single component mechanism, or a dual-component one which sums to produce the total level of inhibition. Incidentally, furthermore, a number of the experiments described here also raised queries for explanations of IOR.

- Attentional focus – The issue of attentional focus was addressed by a few researchers in the 70's and 80's, but has recently waned in popularity. Using both exogenous and endogenous techniques, a number of experiments in this thesis looked at attentional focus size effects and attempted to relate this topic to that of object- and space-based attentional representations. It was predicted that results would produce a reciprocal relationship between the size of attention focus and processing efficiency and that the effects would be modified as a function of the objects in the experimental display.

- Movement of attention – Early work on orienting suggested that attention moved in a smooth fashion across the visual field, whereas later studies have favoured distance independent explanations. Incorporated into the design of a number of the experiments presented here, was a change in the visual angle of targets to which participants had to shift attention and to respond. It was predicted that findings would not support a simple analogue account of attentional orienting.

- Target position markers, landmarks, and placeholders - Few studies have specifically investigated the effects of markers or placeholders, yet they seem to be of vital importance to the results, at least, of detection studies. Some of the experiments described in the following chapters manipulate the presence of placeholders. It was predicted that these would have an impact on the resultant orienting of attention: an absence of cue-markers would produce a reduction in IOR with exogenous cueing and a lack of target position-markers would produce enhanced grouping effects with endogenous cueing.

The following gives a brief outline of each of the remaining chapters:

The experiments in Chapter 2 use LEDs to investigate the effects of abrupt onset exogenous cues on the detection of targets. These targets were either the same LED as the cue, or spatially distinct (separated by 8^0 from the cue), or spatially separated from the cue and presented in a box-like array. The cue-target contingencies were also manipulated so that cues could be spatially informative or uninformative about the possible location of a target. Despite these probability manipulations not being made explicit to participants it was suggested that these more goal-directed forms of attentional control would have an impact on the results.

Chapter 3 looks at the effects of manipulating the attentional focus size, and the presence of cue-markers on inhibition of return. Previous work has suggested that increasing the attentional focus will reduce the efficiency of processing information. Tipper and his colleagues have proposed that the effects of space-based and object-based IOR are additive. The use of different forms of display should provide further information about this proposal. Additionally, the aim of these experiments was to replicate previous exogenous cueing studies, to help produce appropriate stimuli for endogenous cueing work, and to use results to aid explanations of experiments presented in later chapters.

Chapter 4 presents experiments which attempt to use endogenous cueing procedures with a detection task to demonstrate object-based attentional representation. Few studies using static displays have used measures other than divided visual attention tasks and there have been few reported successes at obtaining object-based effects when not using exogenous cueing techniques.

Chapter 5 describes experiments which also use endogenous cueing, but this time not with a simple detection task, but with a task involving judgements about location. Previous studies have shown that altering the task demands of an experiment as well as a move from central to peripheral locations may elicit a different form of attentional representation.

Chapter 6 includes a review of the experimental work as well as a general discussion of the results in relation to the attentional themes mentioned at the beginning of this section.

Chapter 2
The effects of abrupt onset informative and uninformative visual cues on the detection of targets that were spatially the same as or distinct from the cue.

2.1 General Introduction

The following chapter describes six preliminary experiments in which participants were asked to maintain fixation throughout the experiment but to direct their attention covertly to abrupt luminance changes, LED cues, positioned at various eccentricities to the left and right. The task was to make a simple key press as quickly as possible to a red LED target which followed a cue. The experimental procedure was loosely based on exogenous cueing studies carried out by Posner and his colleagues (e.g. Posner and Cohen, 1984), but differed in a number of ways as will be evident from the descriptions that follow. The aim of these initial experiments was to check the replicability of previous findings and to extend these to investigate the effects of informative and 'uninformative' exogenous peripheral cues before embarking on a series of studies which involved both exogenous peripheral and endogenous central cueing studies (described in later chapters).

Posner and Cohen (1984) presented three boxes centred horizontally on a screen which marked the possible locations of the target to which the participant was asked to respond. An abrupt luminance increment of one of the peripheral boxes acted as the cue followed by the onset of the target (a small square) within one of the boxes. Following a variable SOA, the target appeared with high probability (p=0.6) in the central box, and with lower probability (p=0.1) in the cued or uncued peripheral locations. The remaining trials (p=0.2) were catch trials where no target appeared. Targets located in the central box were responded to fastest at all SOAs tested. Targets located in the cued box were detected faster than those appearing at the uncued location when the SOAs were short. However, at SOAs of 300 ms and longer, reaction times to the target were significantly slower when it appeared at the cued than at the uncued location.

Nygaard and Frumkes (1982) described the properties of Light Emitting Diodes (LEDs) and highly recommended them as their "extreme low cost...availability, and versatility...make them an attractive alternative to the usual more cumbersome light sources." (p435) The experiments described in Chapter 2 use LEDs as the stimuli.

In Experiment 1 of this thesis, the display simply used three LEDs: a centred constantly illuminated LED acted as a fixation point with two LEDs positioned 8^0 to the left and to the right of this central light. The aim was to use the onset of a peripheral LED (the cue) to indicate the appearance of a target which could appear in the Same location as the cue (in fact the same LED) or on the Opposite side of fixation to the cue. As in the Posner and Cohen (1984) study the probability of the target appearing in the Same (their 'cued' condition) or Opposite location (their 'uncued' condition) was equal. There were however no occasions when the target did not appear on the Same side or the Opposite side (i.e. no central targets or catch trials) so, the probability of a Same side target was 0.5 as was the probability of an Opposite side target.

In Experiment 2 the same display and procedure was used to that of Experiment 1, but this time the probability of a target occurring on the Same side as the cue was approximately 71% and the probability of an Opposite side target was approximately 29%. The aim of this manipulation was to see whether changing the probabilities of events would produce similar results to those found in Experiment 1 or whether the introduction of perhaps a different top-down goal-directed form of attentional control would affect the outcome.

Experiments 3 and 4 used different LEDs to indicate the positions of the cue and target. In these two studies, five LEDs were used: again a central constantly illuminated yellow LED acted as the fixation point but this time two red LEDs were positioned 8^0 to the left and to the right of fixation and two red LEDs positioned 16^0 to the left and to the right of fixation. The two 8^0 red LEDs acted as the cues and the two 16^0 red LEDs acted as the targets. The aim here was to investigate whether different objects acting as the cue and target in different locations would produce a similar or different pattern of results to those of Experiments 1 and 2.

Experiments in the late 70's and early 80's (e.g. Shulman et al, 1979; Tsal, 1983) suggested that the attentional spotlight moved in an analogue fashion so that the further the distance to be travelled the longer the time taken. Later work, however, (e.g. Sagi & Julesz, 1985; Kwak et al, 1991; Sperling & Weichselgartner, 1995) has shown that attention can jump over locations, objects, and obstacles without a time cost. Shifts of attention are considered as fast and noninertial (Sagi & Julesz, 1985) and quantal (Sperling & Weichselgartner, 1995). So, a further aim of Experiments 3 and 4 is to examine whether RTs to these 16^0 targets resulted in generally longer RTs than those to targets at 8^0.

In Experiment 3 the probability of Same and Opposite side targets was equal (p=0.5), whereas in Experiment 4 the probabilities of targets occurring were 71% and 29% respectively.

Experiments 5 and 6 again used LEDs but the attempt here was to create two 'Posner-like' box arrays positioned to the left and right of fixation. The expectation here was to reproduce earlier exogenous cueing findings using 50% probabilities in Experiment 5 and investigate a change of cue/target probabilities in Experiment 6.

2.2 Experiment 1

The effects of uninformative exogenous cues in identical spatial locations to targets.

2.2.1 Introduction

It is well known that some visual events will automatically induce shifts of attention. Indeed, as early as 1890, William James commented that certain stimuli such as "strange things, moving things, wild animals, bright things..." have a "directly exciting quality" (James 1890, pp416-417). He referred to this form of attention as passive and immediate. Work in the 70's and 80's indicated that attention in the absence of eye movements could be automatically directed to specific spatial locations by, for example, a bar marker indicating a display location (Eriksen and Hoffman, 1973), or a luminance increment (e.g. Posner, 1978, 1980). Jonides (1981) and later Remington, Johnston, and Yantis (1992) specifically examined the issue of automaticity of attentional capture by spatial cues. They found that even with explicit instructions to ignore them, peripheral luminance changes could not be suppressed and brought about substantial reaction time differences to cued and uncued targets.

With this background in mind, what was initially considered to be a simple baseline experiment (Experiment 1) was constructed. The intention was to demonstrate similar findings to those previously revealed in such exogenous cueing studies and then explore whether these would also be found with actual (LED), as opposed to computer constructed, displays. Such LED displays have the potential advantage of no phosphor persistence and are more like real world. They have, for example, been used to examine the effects of cueing in depth (Downing & Pinker, 1985; Gawryszewski, Riggio, Rizzolatti & Umiltà, 1987; Couyoumdjian, Di Nocera, Ferlazzo, 2003).

As mentioned in the General Introduction to this chapter, the experimental procedure was based on an elegant methodology developed by Posner and his colleagues in the 1980s, and is one that is still being used in more recent times (e.g. Müller & Rabbitt ,1989; Folk & Remington, 1999; Schendel, Robertson & Treisman, 2001; Spalek & Hammad, 2004). In Experiment 1, the display simply used three LEDs: a centred constantly illuminated LED acted as a fixation point with two LEDs positioned 8^0 to the left and to the right of this central light. The aim was to use the onset of a peripheral LED (the cue) to indicate the appearance of a target which, following a variable SOA, could appear in the Same location as the cue (in fact the same LED) or on the Opposite side of fixation to the cue. The probability of the target appearing in the Same or Opposite location was equal. There were no occasions when the target did not appear on the Same side or the Opposite side (i.e. no central targets or catch trials) so, the probability of a Same side target was 0.5 as was the probability of an Opposite side target.

In their experiment, Posner and Cohen (1984) presumed that the peripheral brightening of a box automatically attracted attention. This produced an advantage for detection of targets located in the cued box over those in the uncued box when SOAs were short (for the first 150 ms). This facilitation was not found at longer SOAs; at SOAs of 300 ms and longer (Posner and Cohen showed effects lasting until about 1-1.5 secs), targets at the cued location were disadvantaged, or inhibited, and hence were responded to more slowly than those at the uncued location. This slowing of reaction times is thought to reflect a bias towards novelty, or put in other words, a bias against returning to already attended spatial locations.

In light of previous findings, it was predicted that there would be an effect of the Cue side manipulation in Experiment 1 such that targets occurring in Same locations would initially be detected faster than those in Opposite locations, but more slowly at longer SOAs. Depending on the size and time course of these facilitatory and inhibitory effects, this might result in a Main effect of the Cue side, but a definite Cue side x SOA interaction should be expected. Furthermore, in line with many other experiments it was presumed that there would be a Main effect of SOA, such that with increasing cue-target SOAs there would be a resultant decrease in target response times.

2.2.2 Method

Participants

Eight participants (five males and three females) aged between 18 and 29 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates and postgraduates at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour.

All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was run using an Apple Macintosh Performa 630. The LEDs, were driven by digital output and the timing of the experiment was controlled by a purpose written programme. The keyboard space bar was used as the response key.

Participants placed their chin on a rest to limit head movements throughout the session. This was fixed to produce a 57cm viewing distance aligned with the central fixation point.

Stimuli

The stimuli used in this experiment were three circular LEDs measuring 3mm in diameter. They were mounted on a black panel: a centred yellow LED, driven by a 9-volt battery, acted as the fixation point and was visible throughout the experiment; two red LEDs positioned 8^0 to the left and to the right of fixation. These red LEDs acted both as the cues and as the targets.

Design

The design was a within-subjects design with 2 independent variables: Cue side (2 levels: Same, Opposite) and SOA (5 levels: 150, 300, 450, 600, 750 ms). The dependent variable was the mean response time to detect a target.

Procedure

The participant was seated in front of the LED 'screen' and the chin rest adjusted so that the participant's eyes were level with the central fixation point. The procedural instructions were given verbally and any questions about the task were answered.

The central yellow LED was already illuminated at the start of the experiment and remained on throughout. Participants were asked to fixate this yellow LED and not to move their eyes from this central location during the experimental trials. A key press initiated the start of the first of three blocks of trials. Following a random interval (ranging from 400-900 ms) one of the two red LEDs was switched on for 100 ms – this was termed the 'cue'. After a variable SOA (150, 300, 450, 600, or 750 ms) either the same LED (a 'Same' side trial) or the one on the opposite side of fixation (an 'Opposite' trial) was illuminated – this second light was termed the 'target'. The target remained visible until the participant responded with a single key press. After a random inter-trial interval (ITIs ranged from 400-900 ms) the next trial began. At the end of each block of trials, participants were allowed a short break before continuing with the experiment.

Participants were not told about the precise relationship between the cue and target (i.e. that the cue was spatially uninformative), although they were told that the target would follow the cue with SOAs of 150, 300, 450, 600, or 750 ms.

The task was one of a simple reaction time, that is, a single key press to the onset of a target LED. Participants were asked to respond as quickly as possible. The reaction-time key was placed to enable ease of response with the index finger by the participant's preferred hand, and this key was also used to initiate the first trial in each block. The room lights were turned off. The participant was given a number of practice trials to familiarise them with the situation before starting the experiment proper.

Following the end of the experimental session the participants were debriefed and any questions about the experiment answered.

There were 140 trials in each of the three blocks giving a total of 420 trials. Half of these were 'Same' trials (i.e. a left cue LED followed by a left target LED, or a right cue LED followed by a right target LED; an equal number of each type was included) and half were 'Opposite' trials (i.e. either a left cue LED followed by a right target LED, or a right cue LED followed by a left target LED; an equal number of each type was included). Each trial type was presented an equal number of times at each of the five SOAs.

Throughout all of the experiments detailed in this thesis, participants were asked to fixate a central location and not to move their eyes. No eye movement recording equipment was involved in experiments and no check was made that all participants maintained fixation. Hence, no trials were eliminated on the basis of eye movements. Pratt, Spalek, and Bradshaw (1999) note that when large salient cues and targets are used, there is little difference in performance between participants who are monitored for eye movements from those who are unmonitored. So, on the basis of this and of many other reports of participants being able to keep their eyes fixated, I felt fairly confident about using the responses obtained in the experiments without having eye movements monitored.

2.2.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater than or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean[1] RTs were calculated for each of the eight participants for 'Same' and 'Opposite' trials at each of the 5 SOAs (i.e. 150, 300, 450, 600, 750 ms). The means are shown in Table 2.1 below.

Previous studies have shown a bias in favour of responding to targets in the right visual field (e.g. Castiello & Umiltá, 1990). Since this bias was not of interest results throughout this thesis were always collapsed over right and left targets but matched for trial type.

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and five levels of the second factor: SOA (150, 300, 450, 600, 750 ms).

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1 Use of means in analyses: Since the skewness of RTs was altered by eliminating anticipations and any particularly long responses, it was decided that the most appropriate measure of central tendency to use in the experiments throughout this thesis was the mean (rather than the median, or indeed some other measure). Also no transforms were used on the data sets, other than the elimination of trials already described.

Table 2.1 Mean RTs (ms) to 'Same' and 'Opposite' side cue trials at 5 SOAs (Cue & Target the same LED – Same 50%, Opposite 50%)

Same light (50%:50%)		Cue side		
		'Same'	'Opposite'	Mean
SOA	150	326.3	300.8	313.5
	300	279.9	257.1	268.5
	450	264.8	243.1	253.9
	600	250.9	234.6	242.8
	750	241.5	232.4	236.9
	Mean	272.7	253.6	263.1

The ANOVA produced a significant main effect of the 'Cue side' manipulation ($F(1,7) = 6.1$, $p=0.043$). As is apparent from the table of means above (see Table 2.1) and Figure 2.1 below, all (i.e. at each of the SOAs) the 'Same' means were larger than the 'Opposite' means; the overall mean RT for Same trials (272.7 ms) was 19.1 ms longer than the overall mean for Opposite trials (253.6 ms).

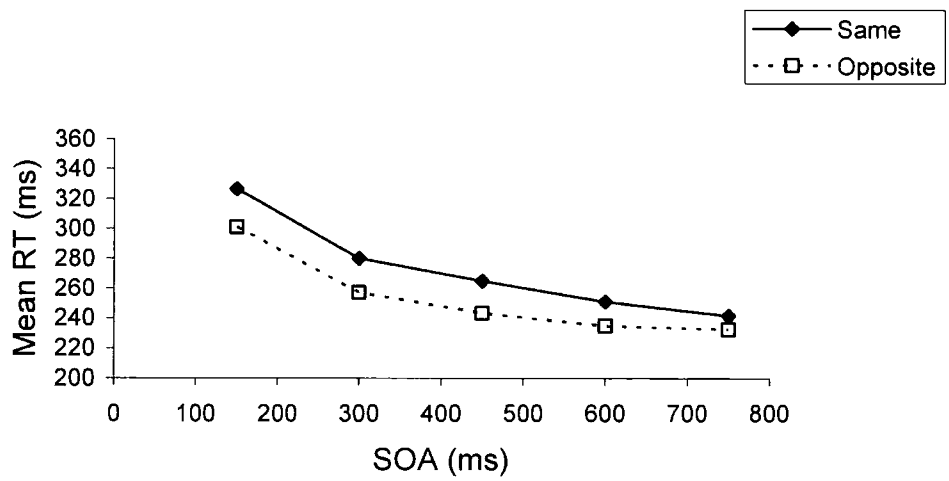


Figure 2.1 Same light (50%:50%): Mean RT to Same and Opposite cued targets

A significant main effect of SOA was found ($F(1.286, 9.002) = 61.8$, $p<0.001$). Comparing the mean RTs at each SOA, it is clear that as SOA increases, RT decreases (from 313.5 ms at an SOA of 150 ms to 236.9 ms at an SOA of 750 ms). Post-hoc Bonferroni tests revealed significant differences between all the SOAs (to at least $p=0.028$) except the comparison between 600 ms and 750 ms which was not significant ($p=0.406$).

The interaction between 'Cue side' and SOA was not significant ($F(4,28) = 1.98$, $p=0.125$).

An additional set of ANOVA calculations was also completed to elicit any effects due to learning of the cue-target contingencies: Separate analyses were carried out for the first and third experimental blocks of trials in addition to a comparison between these two blocks.

The pattern of results for the individual blocks was identical to the 'over all blocks' analysis described above:

Block 1 produced significant main effects of 'Cue side' ($F(1,7) = 6.473$, $p=0.047$) and SOA ($F(1.286, 9.002) = 23.97$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,28) = 5.194$, $p=0.063$).

Block 3 also showed significant main effects of 'Cue side' ($F(1,7) = 6.36$, $p=0.041$) and SOA ($F(4, 28) = 23.035$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,28) = 0.472$, $p=0.756$).

There was no significant difference between the blocks of trials ($F(1, 7) = 0.171$, $p=0.692$).

2.2.4 Discussion

As has been found in numerous experiments varying the onset time between cue and target, the predicted main effect of SOA on RTs was found: as SOA increased, reaction times to targets (whether on the Same side or the Opposite side to the cue) decreased. The cue although spatially uninformative (i.e. it did not predict the location of the forthcoming target) did provide some temporal information - participants knew that a target would occur within 750 ms – and it is this information that is likely to have produced this main SOA effect.

The results also showed a significant Main effect of Cue side. However this was not as expected: Same side targets were significantly slower (on average by 19.1 ms) to be detected than those targets occurring on the Opposite side to the cue and this was true at all but the longest SOAs. There was also a non-significant interaction between Cue side and SOA.

What might account for these unexpected findings? When designing this experiment, it was thought that the task would be relatively simple and straightforward. In fact, participants commented that the task was sometimes quite difficult. When the cue and the target were in different locations (Opposite cue side trials), participants found the detection of targets relatively easy. However, when the cue and the target were in the same location (in fact the same LED illuminated twice in succession), participants found it harder to discriminate between the cue and the target, and, as one participant commented, “especially if you lost track of which of the lights [first or second] you should be responding to”.

Although it is apparent that there were discrimination problems, it is also possible that the relatively blank visual field may have failed to produce facilitatory effects. Experiments in the 50’s and 60s which used dim flashes (e.g. Mertens, 1956) or brief presentations of a single letter (e.g. Grindley & Townsend, 1968) in otherwise empty displays, also did not produce attentional effects and concluded that attention to location has no influence on the probability of observation or ability to improve discriminability. The main difference between these experiments (including my Experiment 1) and other later studies which have produced evidence for directed attention (see Shiu & Pashler, 1994 for a review), is that the latter have displays where potentially competing visual stimuli are present.

So, to conclude, it seems that the presence of an abrupt 'uninformative' luminance change does produce some reaction time differences to cued and uncued targets, but not as expected: If the cue signals a target which is the same object in the same location, no beneficial, or facilitatory, attentional effects are found for RTs to that location; instead it seems that only an increase of RTs to Same side targets (or possibly a decrease in RTs to Opposite side targets) is evident.

2.3 Experiment 2
The effects of informative exogenous cues in identical spatial locations to targets.

2.3.1 Introduction

Helmholtz (1866/1925) whilst carrying out an experiment on depth perception noted that "it is possible by a conscious and voluntary effort, to focus the attention on some definite spot" (p455). This was one of the first indications that attention could be characterized as goal-directed as opposed to directed by external events, or automatically stimulus-driven.

In 1980, Posner, Snyder and Davidson published the first of many experiments using central symbolic cueing. Participants were asked to react as quickly as possible to a visual target occurring to the left or right following a neutral, valid, or invalid cue presented at fixation. When the cue was valid (e.g. an arrow correctly indicating the location of a target on 80% of such trials) participants' RTs were speeded relative to those targets following a neutral cue (e.g. a cross representing targets of equal probability to the left and right). When the cue was invalid (e.g. an arrow correctly indicating the location of a target on 20% of such trials) RTs to targets was slowed relative to a neutral cue. These symbolic directional cues are thought to require processing and are thought of as directed by an internal attentional plan, or goal-directed.

Initially peripheral exogenous cues (e.g. as described in Posner and Cohen (1984) above) and symbolic cues were thought of as two different methods of controlling the same attentional orienting system (Posner, 1980; Jonides, 1981). However, Müller and Findlay (1989) and Müller and Rabbitt (1989) proposed that, since they had found different time courses for the costs and benefits produced by exogenous and symbolic cues, that there was evidence for two separate orienting mechanisms that could be acting simultaneously. (Further evidence for this view also comes from Nakayama and Mackeben, 1989; and Cheal and Lyon, 1991; although not all experimenters subscribe to this opinion.)

Folk and his co-workers (e.g. Folk, Remington & Johnston, 1992; Folk, Remington & Wright, 1994; see also Yantis, 1998) proposed the idea that the deployment of attention involves an "attentional control setting". The set of goals and intentions of a person (which can be naturalistic e.g. find a book, or the results of experimental instructions e.g. search for a red circle) will interplay with the properties of an image to determine how attention is allocated. That is they proposed an interaction between goal-directed and stimulus-driven attentional control

In Experiment 2 the same display and procedure were used to that of Experiment 1, but the probabilities of Same and Opposite trials were altered. The probability of a target occurring on the Same side as the cue was approximately 71% and the probability of an Opposite side target was approximately 29%.

It seems not unreasonable to suggest than even in unnatural laboratory experiments there are likely to be interactions between goal-driven and stimulus-driven forms of attentional control. So, even though participants were not aware of a cue probability manipulation – they were simply told that a target would follow a cue after a varying SOA – the intention of this experiment was to see if such probability alterations in exogenous cues would produce similar results to those found in Experiment 1 or whether the introduction of perhaps a different albeit unconscious top-down goal-directed form of attentional control would affect the outcome.

If the exogenous cues in Experiment 2 act by 'simply' automatically capturing attention, then any probability manipulation should have no effect on the RTs, and the results produced should be similar to those of Experiment 1. If, however, somehow the participants' attentional settings are shifted throughout the experiment, then we might expect different results. It seems intuitively possible that results obtained would be akin to those found by Posner, Snyder and Davidson (1980) in their symbolic cueing studies.

2.3.2 Method

Participants

Eight participants (four males and four females) aged between 18 and 21 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates and postgraduates at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour.

All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus, Stimuli and Design

The apparatus, stimuli and design were as described in Experiment 1.

Procedure

The procedure was identical to that used in Experiment 1 except that the proportion of 'Same' and 'Opposite' trials was altered. Participants were not told about the precise relationship between the cue and target (i.e. that the cue was spatially informative), although they were told that the target would follow the cue with SOAs of 150, 300, 450, 600, or 750 ms.

There were again 140 trials in each of the three blocks giving a total of 420 trials. In this experiment, however, approximately 71% were 'Same' trials (N=300) and approximately 29% were 'Opposite' trials (N=120); each trial type was presented an equal number of times at each of the five SOAs.

2.3.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater than or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the eight participants for 'Same' and 'Opposite' trials at each of the 5 SOAs (i.e. 150, 300, 450, 600, 750 ms). The means are shown in Table 2.2 below.

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and five levels of the second factor: SOA (150, 300, 450, 600, 750 ms).

Table 2.2 Mean RTs (ms) to 'Same' and 'Opposite' side cue trials at 5 SOAs (Cue & Target the same LED – Same 71%, Opposite 29%)

Same light (71%:29%)		Cue side		
		'Same'	'Opposite'	Mean
SOA	150	329.1	331.8	330.4
	300	285.6	298.6	292.1
	450	271.5	279.6	275.6
	600	266.4	269.1	267.8
	750	254.0	273.4	263.7
	Mean	281.3	290.5	285.9

Looking at the table of means above (see Table 2.2) and Figure 2.2 below, all (i.e. at each of the SOAs) the 'Same' means were smaller than the 'Opposite' means; the overall mean RT for Same trials (281.3 ms) was 9.2 ms shorter than the overall mean for Opposite trials (290.5 ms). However, this main effect of the 'Cue side' did not reach significance ($F(1,7) = 3.9$, $p = 0.090$).

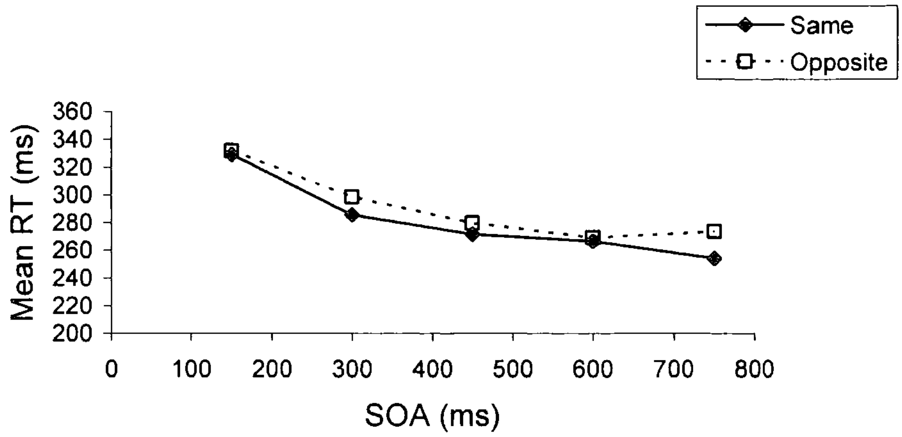


Figure 2.2 Same light (71%:29%): Mean RT to Same and Opposite cued targets

The ANOVA revealed a significant main effect of SOA (F(1.425, 9.976) = 25.3, p<0.001). Comparing the overall mean RTs at each SOA, it is clear that as SOA increases, RT decreases (from 330.4 ms at an SOA of 150 ms to 263.7 ms at an SOA of 750 ms). Post-hoc Bonferroni tests revealed significant RT differences at the SOA of 150 ms and at all the other SOAs (to at least p=0.014); RTs were significantly different at 300 ms SOA and 750 ms SOA (p=0.009); the remaining comparisons (i.e. 300 ms vs. 450 ms and 600 ms; 450 ms vs. 600 ms and 750 ms; and 600 ms vs. 750 ms) were not significant.

The interaction between 'Cue side' and SOA was not significant (F(1.531, 10.7) = 2.041, p=0.181).

An additional set of ANOVA calculations was also completed to elicit any effects due to learning of the cue-target contingencies: Separate analyses were carried out for the first and third experimental blocks of trials in addition to a comparison between these two blocks.

The pattern of results for the individual blocks was identical to the 'over all blocks' analysis described above:

Block 1 produced a non significant main effect of 'Cue side' ($F(1,7) = 3.664$, $p=0.097$), a significant main effect of SOA ($F(1.286, 9.002) = 29.153$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,28) = 0.724$, $p=0.583$).

Block 3 also showed a non significant main effect of 'Cue side' ($F(1,7) = 3.745$, $p=0.094$), a significant main effect of SOA ($F(4, 28) = 22.328$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,28) = 1.472$, $p=0.316$).

There was no significant difference between the blocks of trials ($F(1, 7) = 0.171$, $p=0.692$).

2.3.4 Discussion

As in Experiment 1, there was an unsurprising significant effect of SOA: as SOA increases, RT decreases. It is noted that the overall mean times were slightly longer (but not significantly so) in this experiment however: scores decreasing from 330.4 ms at an SOA of 150 ms to 263.7 ms at an SOA of 750 ms, as opposed to those in Experiment 1 which decreased from 313.5 ms to 236.9 ms. Though since different participants were used in the two studies and it is well known that there are large individual variations in reaction times in such situations, not much more can be added to this note.

In Experiment 1 Same side targets were detected significantly slower than Opposite side targets. In this experiment 'Same' RT means were smaller than the 'Opposite' means, but this did not quite reach significance ($p=0.09$). There was also a non-significant interaction between Cue side and SOA.

Despite these non-significant results which were neither in line with Experiment 1 nor with previous work using exogenous or symbolic cueing, this experiment has yielded an important finding: changing the cue/target probabilities has altered the outcome. Participants still commented on the difficulty of discriminating between Same trials cue and target, but clearly the expectancies do seem to have brought about at least some change, whether this is the result of a change of interplay between internal goal-directed and stimulus-driven forms of control, or for some other reason is not clear.

2.4 Experiment 3

The effects of uninformative exogenous cues in different spatial locations to the more peripheral targets.

2.4.1 Introduction

Results of Experiments 1 and 2 indicated that abrupt uninformative and informative luminance increments do produce attentional changes although these were not as expected based on previous work in this area. One of the main problems of these initial experiments is that participants commented on the difficulty of discriminating between the cue and the target in Same side cue trials. This discrimination effect could have produced elevated reaction times to Same side targets, which although were apparently reduced by the change in cue/target probability in Experiment 2, still did not produce results equivalent to earlier experiments.

Experiment 3 therefore clearly spatially separated the cue and the target (although the colour was not altered). Five LEDs were used: a central constantly illuminated yellow LED acted as the fixation point but this time two red LEDs were positioned 8^0 to the left and to the right of fixation and two red LEDs positioned 16^0

to the left and to the right of fixation. As in Experiments 1 and 2, the two 8^0 red LEDs acted as the cues, but here the two 16^0 red LEDs acted as the targets. As in Experiment 1 the probability of a target occurring on the Same side as the cue was equal to the probability of a target occurring on the opposite side to the cue (i.e. p=0.5).

The aim here was to investigate whether different objects acting as the cue and target in different locations would produce a similar or different pattern of results to those of Experiments 1 and 2. If the main problem in Experiments 1 and 2 was one of discrimination and this problem had indeed been eliminated, then results in Experiment 3 should probably be similar to those found in other exogenous cueing studies. If however, the main problem was a continued lack of competing visual stimuli (even though there were five LEDs used in this experiment, as in Experiments 1 and 2, only two LEDs were ever visible at any one time), then results would be consistent with those in Experiment 1.

As mentioned in the General Introduction to this Chapter, experiments in the late 70's and early 80's (e.g. Shulman et al, 1979; Tsal, 1983) suggested that an attentional spotlight moved at a constant speed in an analogue fashion so that the further the distance to be travelled the longer the time taken. However, these findings were contaminated by changes in arousal that accompany a cue. Remington and Pierce (1984) were able to decouple the non-spatial warning/arousal effect from the spatially specific attentional effect and they concluded that the time needed to shift attention is independent of the distance to be travelled. Further work has corroborated this finding (e.g. Sagi & Julesz, 1985; Kröse & Julesz, 1989; Kwak, Dagenbach & Egeth, 1991; Sperling & Weichselgartner, 1995). These workers have shown that attention can jump over locations, objects, and obstacles without a time cost. Shifts of attention are considered as fast and noninertial (Sagi & Julesz, 1985) and quantal (Sperling & Weichselgartner, 1995).

So, a further, though secondary, aim here was to compare the overall times taken in this experiment to move attention to the 16^0 targets with the time taken to move attention in Experiments 1 and 2 to targets at 8^0. However, no neutral comparison cue is available here and the participants used in the experiments were not the same, so this comparison can only lead to tentative conclusions.

2.4.2 Method

Participants

Seven participants (five males and two females) aged between 19 and 23 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates and postgraduates at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was run using an Apple Macintosh Performa 630. The LEDs, were driven by digital output and the timing of the experiment was controlled by a purpose written programme. The keyboard space bar was used as the response key.

Participants placed their chin on a rest to limit head movements throughout the session. This was fixed to produce a 57cm viewing distance aligned with the central fixation point.

Stimuli

The stimuli used in this experiment were five circular LEDs measuring 3mm in diameter. They were mounted in a black panel: a central yellow LED, driven by a 9-volt battery, acted as the fixation point and was visible throughout the experiment; two red LEDs positioned 8^0 to the left and to the right of fixation; two red LEDs positioned 16^0 to the left and to the right of fixation. The two 8^0 red LEDs acted as the cues and the two 16^0 red LEDs acted as the targets.

Design

The design was a within-subjects design with 2 independent variables: Cue side (2 levels: Same, Opposite) and SOA (5 levels: 150, 300, 450, 600, 750 ms). The dependent variable was the mean response time to detect a target.

Procedure

The participant was seated in front of the LED 'screen' and the chin rest adjusted so that the participant's eyes were level with the central fixation point. The procedural instructions were given verbally and any questions about the task were answered.

The central yellow LED was already illuminated at the start of the experiment and remained on throughout. Participants were asked to fixate this yellow LED and not to move their eyes from this central location during the experimental trials. A key press initiated the start of the first of three blocks of trials. Following a random interval (ranging from 400-900 ms) one of the two 8^0 red LEDs was switched on for 100 ms – this is termed the 'cue'. After a variable SOA (150, 300, 450, 600, or 750 ms) either the LED at 16^0 on the same side of fixation (a 'Same' side trial) or the LED at 16^0 on the opposite side of fixation (an 'Opposite' trial) was illuminated – this second light at 16^0 is termed the 'target'. The target remained visible until the participant responded with a single key press. After a random inter-trial interval (ITIs ranged from 400-900 ms) the next trial began. At the end of each block of trials, participants were allowed a short break before continuing with the experiment.

Participants were not told about the precise relationship between the cue and target (i.e. that the cue was spatially uninformative), although they were told that the target would follow the cue with SOAs of 150, 300, 450, 600, or 750 ms.

The task was one of a simple reaction time, that is, a single key press to the onset of a target LED. Participants were asked to respond as quickly as possible. The reaction-time key was placed to enable ease of response with the index finger by the participant's preferred hand, and this key was also used to initiate the first trial in each block. The room lights were turned off. The participant was given a number of practice trials to familiarise them with the situation before starting the experiment proper.

Following the end of the experimental session the participants were debriefed and any questions about the experiment answered.

There were 140 trials in each of the three blocks giving a total of 420 trials. Half of these were 'Same' trials (i.e. a left 8^0 cue LED followed by a left 16^0 target LED, or a right 8^0 cue LED followed by a right 16^0 target LED; an equal number of each type were included) and half were 'Opposite' trials (i.e. either a left 8^0 cue LED followed by a right 16^0 target LED, or a right 8^0 cue LED followed by a left 16^0 target LED; an equal number of each type was included). Each trial type was presented an equal number of times at each of the five SOAs.

2.4.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater than or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the seven participants for 'Same' and 'Opposite' trials at each of the 5 SOAs (i.e. 150, 300, 450, 600, 750 ms). The means are shown in Table 2.3 below.

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and five levels of the second factor: SOA (150, 300, 450, 600, 750 ms).

Looking at the table of means (see Table 2.3) and Figure 2.3 below, all (i.e. at each of the SOAs) the 'Same' means were smaller than the 'Opposite' means; the overall mean RT for Same trials (264.5 ms) was 2.7 ms shorter than the overall mean for Opposite trials (267.2 ms). However, this main effect of the 'Cue side' was not significance ($F(1,6) = 0.6$, $p= 0.470$).

The ANOVA did produce a significant main effect of SOA ($F(4, 24) = 72.3$, $p<0.001$). Comparing the overall mean RTs at each SOA, it is apparent that as SOA increases, RT decreases (from 304.4 ms at an SOA of 150 ms to 247.4 ms at an SOA of 750 ms). Post-hoc Bonferroni tests revealed significant RT differences at the SOA of 150 ms vs. all the other SOAs (to at least $p=0.003$); RTs were also significantly different at 300 ms SOA vs. all the other SOAs ((to at least $p=0.019$); the remaining comparisons (i.e. 450 ms vs. 600 ms and 750 ms; 600 ms vs. 750 ms) were not significant.

Table 2.3 Mean RTs (ms) to 'Same' and 'Opposite' side cue trials at 5 SOAs (Cue: Near; Target: Far – Same 50%, Opposite 50%)

Cue: Near; Target: Far (50%:50%)		Cue side		
		'Same'	'Opposite'	Mean
SOA	150	303.4	305.3	304.4
	300	271.4	273.8	272.5
	450	251.0	259.3	255.1
	600	249.4	250.1	249.8
	750	247.0	247.9	247.4
	Mean	264.5	267.2	265.8

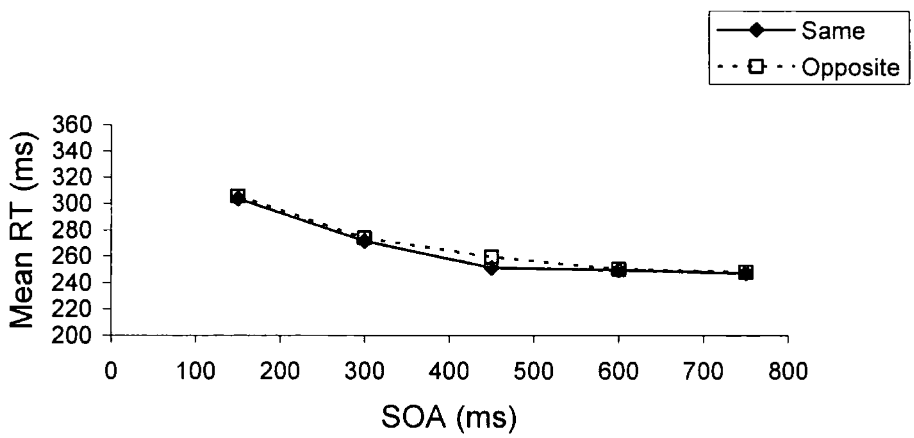


Figure 2.3 Cue: Near, Target: Far (50%:50%): Mean RT to Same and Opposite cued targets

The interaction between 'Cue side' and SOA was not significant ($F(1.135, 6.809) = 0.4$, $p=0.779$).

An additional set of ANOVA calculations was also completed to elicit any effects due to learning of the cue-target contingencies: Separate analyses were carried out for the first and third experimental blocks of trials in addition to a comparison between these two blocks.

The pattern of results for the individual blocks was identical to the 'over all blocks' analysis described above:

Block 1 produced a non significant main effect of 'Cue side' ($F(1,6) = 0.285$, $p=0.613$), a significant main effect of SOA ($F(4, 24) = 63.9$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,24) = 0.844$, $p=0.511$).

Block 3 also showed a non significant main effect of 'Cue side' ($F(1,6) = 2.644$, $p=0.155$), a significant main effect of SOA ($F(4, 28) = 42.960$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,24) = 1.058$, $p=0.399$).

There was no significant difference between the blocks of trials ($F(1, 6) = 0.334$, $p=0.585$).

2.4.4 Discussion

As in Experiment 1 and 2, there was the usual significant effect of SOA: as SOA increases, RT decreases. It is interesting to note, however, that the overall mean times here were shorter than those in Experiments 1 (at 150 ms SOA) and Experiment 2 (at all SOAs): scores decreased from 304.4 ms at an SOA of 150 ms to 247.4 ms at an SOA of 750 ms as compared to 313.5 ms to 236.9 ms in Experiment 1 and 330.4 ms to 263.7 ms in Experiment 2. (However, none of these comparisons reached significance.)

In the Introduction it was suggested that if problems of discrimination and lack of competing visual stimuli were not an issue, then results might be similar to those of other exogenous cueing studies such that Same side targets would be responded to faster than Opposite side targets, but only at early SOAs. If the latter problem held true, then the results here should be consistent with those in Experiment 1. Participants reported that the task was a relatively easy one, so it seems that the problems of discrimination were avoided. The issue of competing visual stimuli remains unresolved.

The outcome of the Cue side manipulation produced data that was similar to that found in Experiment 2 not truly matching either of the predictions. The times taken to respond to Same side targets were smaller than those to Opposite side targets, but only on average by 2.7 ms which was not sufficient to produce a significant effect of Cue side. The interaction between 'Cue side' and SOA, as in Experiments 1 and 2, was again not significant.

So, it seems that changing the discriminability of targets, using different objects and locations for cues and targets has brought about a different set of results to those of the two earlier experiments.

Comparing the times taken in this experiment to move attention to the 16^0 targets with the time taken to move attention in Experiments 1 and 2 to targets at 8^0, it is clear that some of the overall times in this Experiment were shorter than those in the two earlier studies: e.g. an overall mean of 265.8 ms vs. 263.1 ms in Experiment 1 and 285.9 ms in Experiment 2. Although individual differences could certainly account for the size of these reaction times, and there is no neutral-alerting comparison cue in any of these experiments, the results do not lend support to the idea that attention moves at a constant rate across the visual field. (It does not preclude the possibility that attention could move at a variable rate: faster to further targets.)

Additionally, because of the discrimination difficulties encountered in Experiments 1 and 2 (e.g. see Discussion of Experiment 1), it would be imprudent to make any firm conclusions about the movement of attention based on comparisons between these experiments. The problem of distinguishing between the 'identical' cue and target in Experiments 1 and 2 may have caused an increase in RTs overwhelming any effects caused by having targets at smaller eccentricities than those in Experiment 3.

2.5 Experiment 4
The effects of informative exogenous cues in different spatial locations to the more peripheral targets.

2.5.1 Introduction

A change in the cue/target probabilities brought about differing results in Experiments 1 and 2. A possible way of describing the effects of the alteration could be to say that the Same side target times had been improved or the Opposite side target times had worsened, or both. A tentative suggestion was that the goal-directed control of attention had been unconsciously altered.

The aim of Experiment 4 was to replicate Experiment 3 with similarly adapted cue/target probabilities to those of Experiment 2 to investigate whether these target predictability changes would produce concomitant RT differences to those found between Experiments 1 and 2.

2.5.2 Method

Participants

Eight participants (five females and three males) aged between 18 and 22 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates and postgraduates at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour.
All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus, Stimuli and Design

The apparatus, stimuli and design were as described in Experiment 3.

Procedure

The procedure was identical to that used in Experiment 3 except that the proportion of 'Same' and 'Opposite' trials was altered. Participants were not told about the precise relationship between the cue and target (i.e. that the cue was spatially informative), although they were told that the target would follow the cue with SOAs of 150, 300, 450, 600, or 750 ms.

There were again 140 trials in each of the three blocks giving a total of 420 trials. In this experiment, however, approximately 71% were 'Same' trials (N=300) and approximately 29% were 'Opposite' trials (N=120); each trial type was presented an equal number of times at each of the five SOAs.

2.5.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater than or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the eight participants for 'Same' and 'Opposite' trials at each of the 5 SOAs (i.e. 150, 300, 450, 600, 750 ms). The means are shown in Table 2.4 below.

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and five levels of the second factor: SOA (150, 300, 450, 600, 750 ms).

Table 2.4 Mean RTs (ms) to 'Same' and 'Opposite' side cue trials at 5 SOAs (Cue: Near; Target: Far – Same 71%, Opposite 29%)

Cue: Near; Target: Far (71%:29%)		Cue side		
		'Same'	'Opposite'	Mean
SOA	150	301.0	315.3	308.1
	300	264.8	285.6	275.2
	450	246.6	266.6	256.6
	600	244.8	256.6	250.7
	750	238.6	262.9	250.8
	Mean	259.2	277.4	268.3

The ANOVA produced a significant main effect of the 'Cue side' ($F(1,7) = 9.5$, $p= 0.018$). Looking at the table of means above (see Table 2.4) and Figure 2.4 below, all (i.e. at each of the SOAs) the 'Same' means were smaller than the 'Opposite' means; the overall mean RT for Same trials (259.2 ms) was 18.2 ms shorter than the overall mean for Opposite trials (277.4 ms).

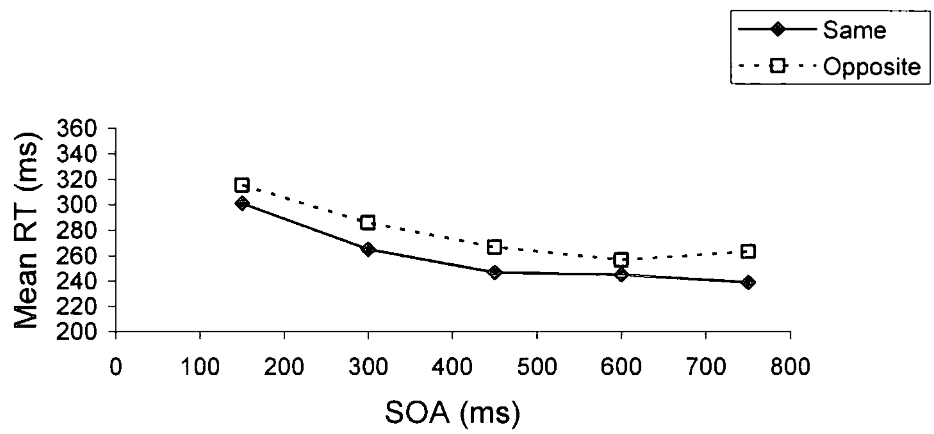


Figure 2.4 Cue: Near, Target: Far (71%:29%): Mean RT to Same and Opposite cued targets

The ANOVA revealed a significant main effect of SOA ($F(4, 28) = 64.8$, $p<0.001$). Comparing the overall mean RTs at each SOA, it is clear that, for the most part, as SOA increases, RT decreases (from 308.1 ms at an SOA of 150 ms to 250.7 ms at an SOA of 600 ms). The mean RT increased slightly from 250.7 ms at 600 ms SOA to 250.8 at 750 ms. Post-hoc Bonferroni tests revealed significant RT differences at the SOA of 150 ms vs. all the other SOAs (all $p<0.001$); RTs were significantly different at 300 ms SOA vs. 450 ms and 600 ms SOAs ($p=0.014$ and $p=0.013$ respectively); the remaining comparisons (i.e. 300 ms vs. 750 ms; 450 ms vs. 600 ms and 750 ms; and 600 ms vs. 750 ms) were not significant.

The interaction between 'Cue side' and SOA was not significant ($F(4, 28) = 0.8$, $p=0.565$).

An additional set of ANOVA calculations was also completed to elicit any effects due to learning of the cue-target contingencies: Separate analyses were carried out for the first and third experimental blocks of trials in addition to a comparison between these two blocks.

The pattern of results for the individual blocks was identical to the 'over all blocks' analysis described above:

Block 1 produced significant main effects of 'Cue side' ($F(1,7) = 13.096$, $p=0.009$) and SOA ($F(1.659, 11.614) = 62.664$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,28) = 0.444$ $p=0.775$).

Block 3 also showed significant main effects of 'Cue side' ($F(1,7) = 11.174$, $p=0.012$) and SOA ($F(4, 28) = 66.065$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,28) = 0.205$, $p=0.933$).

There was a significant difference between the blocks of trials ($F(1, 7) = 13.473$, $p=0.008$). This finding was a result of the significant interaction between Block and SOA ($F(4, 28) = 3.151$, $p=0.029$ (i.e. increased effects of the SOA manipulation over the course of the experiment) rather than any enhanced learning of the cue-target contingencies since the interaction of Block and 'Cue side' was not significant (($F(1, 7) = 1.928$, $p=0.208$) as was the three-way interaction of Block x 'Cue side' x SOA ($F(4, 28) = 0.709$, $p=0.593$).

2.5.4 Discussion

As in the previous 3 experiments, there was a significant effect of SOA: as SOA increases, RT decreases. Generally, overall mean times here were shorter than those in Experiment 2, but slightly longer than those in Experiments 1 and 3.

(This provides further evidence against the continuous movement of attention across the visual field as mentioned in the previous Discussion section. However, RT differences between experiments were not significant.)

The results also showed a significant effect of Cue side: Same side targets were detected significantly faster than Opposite side targets (on average by 18.2 ms). The cue side x SOA interaction was however again not significant. It appears that there were facilitatory effects of the informative cue, but there were no inhibitory effects. The results again were not in line with previous research which would have predicted a Cue side x SOA interaction.

Although it is risky to make comparisons across participants in reaction time studies, looking more closely at the mean times for Experiments 3 and 4 (see Tables 2.3 and 2.4) it is apparent that the mean times for Same trials have decreased from experiment 3 to 4, whereas Opposite mean times have increased (and this is true at all SOAs). Perhaps this change of cue/target expectancy does indeed bring about some alteration in attentional control setting?

2.6 Experiment 5

The effects of uninformative 'box-like' location cues.

2.6.1 Introduction

Since none of the preceding single LED experiments had produced results that were similar to those found by previous exogenous cueing studies, Experiment 5 attempted to create two 'Posner-like' box arrays using LEDs positioned to the left and right of fixation with targets occurring within a cued box at 12^0 in an attempt to replicate (or at least produce comparable results to) the original Posner and Cohen

(1984) study. As comparisons were to be made between this and the previous four experiments, other display characteristics and procedures were kept the same. In Experiment 5 half the trials had targets occurring on the Same side as the cue and half had targets occurring on the Opposite side to the cue.

If the display manages to simulate on-screen conditions, then it would be expected that, as with all earlier experiments, there would be an effect of SOA such that increasing SOAs brought about decreasing RTs. It would also be expected that a Cue side manipulation, or at least a cue side x SOA interaction indicating both facilitation and inhibition of RTs to targets, would be present.

If however, the LED box display resulted in difficulties of discrimination which might happen if participants found the cue and target perceptually too similar, or the additional LEDs too distracting, then results similar to those in Experiment 1 might be expected.

If the LED box display did not present discrimination difficulties, but neither did it simulate on-screen exogenous cueing, then one might expect results comparable to those found in Experiment 3 since targets were presented at eccentricities greater than those in Experiment 1 (i.e. targets appeared at 16^0 in Experiment 3 and 8^0 in Experiment 1).

Furthermore if indeed similar results to those in Experiment 1 are found then one might be tempted to exclude the idea that competing visual stimuli are necessary to produce attentional shifts (as mentioned in the Discussion section of Experiment 1), since in Experiment 5 there are 8 additional LEDs acting as the target position locators (or landmarks) constantly illuminated throughout the entire experiment.

2.6.2 Method

Participants

Seven participants (four males and three females) aged between 18 and 33 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates, postgraduates and staff at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was run using an Apple Macintosh Performa 630. The LEDs, were driven by digital output and the timing of the experiment was controlled by a purpose written programme. The keyboard space bar was used as the response key.

Participants placed their chin on a rest to limit head movements throughout the session. This was fixed to produce a 57cm viewing distance aligned with the central fixation point.

Stimuli

The stimuli used in this experiment were 19 circular LEDs measuring 3mm in diameter. They were mounted in a black panel: a central yellow LED, driven by a 9-volt battery, acted as the fixation point and was visible throughout the experiment; two green LEDs 12^0 to the left and to the right of fixation were the targets; eight red LEDs formed a square around the green LED on the left and a further eight red LEDs formed a square around the green LED on the right of fixation. The four LEDs forming the corners of the two squares were illuminated throughout the experiment. The remaining four, one on each side of each square were flashed on for 100 ms to act as cues.

Design

The design was a within-subjects design with 2 independent variables: Cue side (2 levels: Same, Opposite) and SOA (5 levels: 150, 300, 450, 600, 750 ms). The dependent variable was the mean response time to detect a target.

Procedure

The participant was seated in front of the LED 'screen' and the chin rest adjusted so that the participant's eyes were level with the central fixation point. The procedural instructions were given verbally and any questions about the task were answered.

The central yellow LED was already illuminated at the start of the experiment and remained on throughout. Participants were asked to fixate this yellow LED and not to move their eyes from this central location during the experimental trials. A key press initiated the start of the first of three blocks of trials. At this key press the four red corner LEDs were illuminated and remained on until the end of the block. Following a random interval (ranging from 400-900 ms) one of the two sets of four unlit red LEDs was switched on for 100 ms – these LEDs constituted the 'cue'. After a variable SOA (150, 300, 450, 600, or 750 ms) either the green LED within the cue square (a 'Same' side trial) or the green LED within the uncued square on the opposite side of fixation (an 'Opposite' trial) was illuminated – these green lights were the targets. The green target light remained visible until the participant responded with a single key press. After a random inter-trial interval (ITIs ranged from 400-900 ms) the next trial began. At the end of each block of trials, participants were allowed a short break before continuing with the experiment. (See Figure 2.5 for an example of a 'Same' side trial.)

Participants were not told about the precise relationship between the cue and target (i.e. that the cue was spatially uninformative), although they were told that the target would follow the cue with SOAs of 150, 300, 450, 600, or 750 ms.

The task was one of a simple reaction time, that is, a single key press to the onset of a target LED. Participants were asked to respond as quickly as possible. The reaction-time key was placed to enable ease of response with the index finger by the participant's preferred hand, and this key was also used to initiate the first trial in each block. The room lights were turned off. The participant was given a number of practice trials to familiarise them with the situation before starting the experiment proper.

Following the end of the experimental session the participants were debriefed and any questions about the experiment answered.

There were 140 trials in each of the three blocks giving a total of 420 trials. Half of these were 'Same' trials (i.e. a left box cue followed by a left 12^0 target LED, or a right box cue followed by a right 12^0 target LED; an equal number of each type was included) and half were 'Opposite' trials (i.e. either a left box cue followed by a right 12^0 target LED, or a right box cue followed by a left 12^0 target LED; an equal number of each type was included). Each trial type was presented an equal number of times at each of the five SOAs.

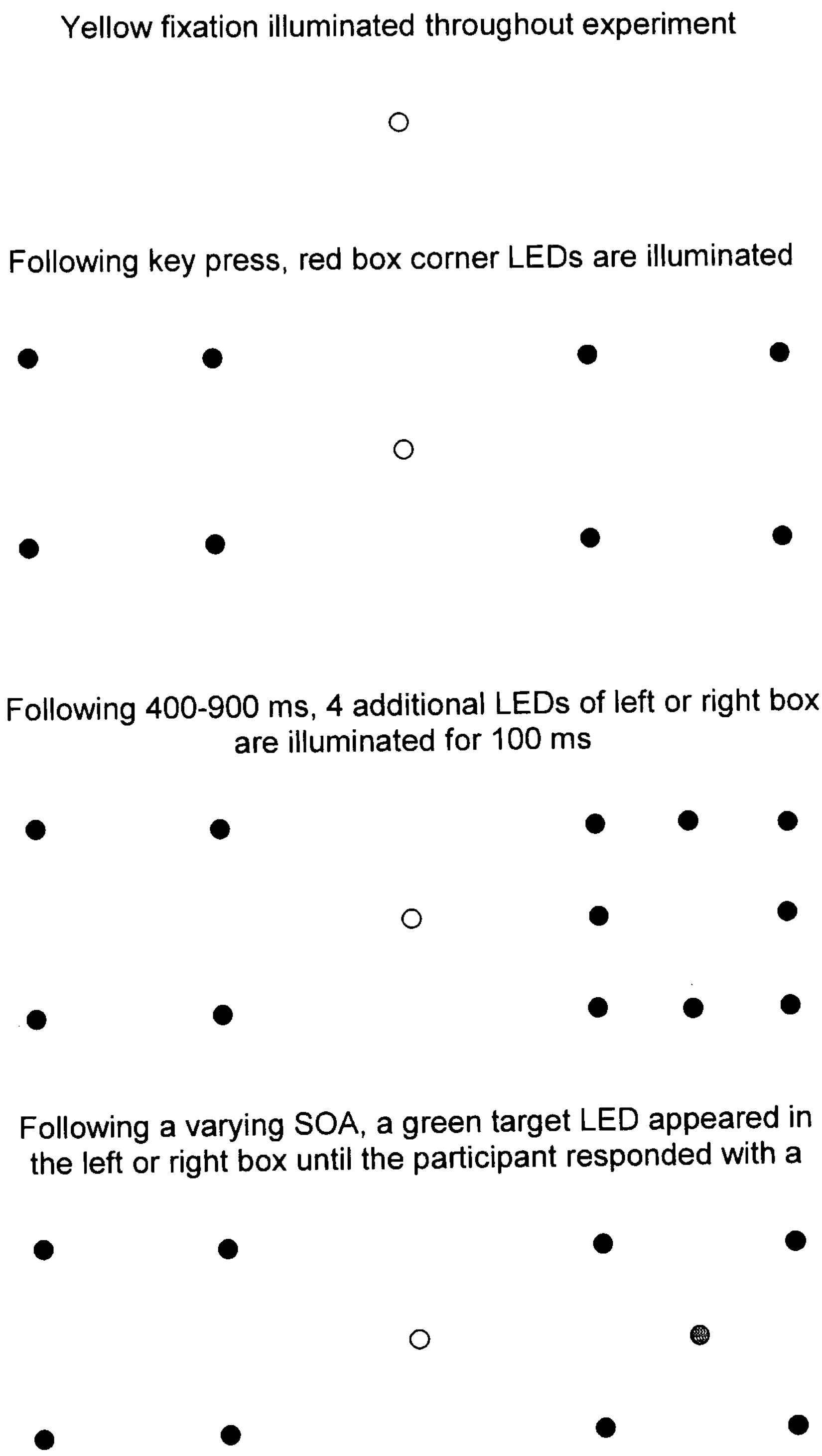


Figure 2.5 Experiment 5: example of a 'Same' side trial

2.6.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater than or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the seven participants for 'Same' and 'Opposite' trials at each of the 5 SOAs (i.e. 150, 300, 450, 600, 750 ms). The means are shown in Table 2.5 below.

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and five levels of the second factor: SOA (150, 300, 450, 600, 750 ms).

There was a significant main effect of the 'Cue side' ($F(1,6) = 43.0$, $p = 0.001$). Looking at the table of means (see Table 2.5) and Figure 2.6 below, four out of five of the 'Same' means (i.e. at each of the SOAs) were larger than the 'Opposite' means; the mean RT at 450 ms SOA was shorter for 'Same' than for 'Opposite' conditions; the overall mean RT for Same trials (281.3 ms) was 10.4 ms longer than the overall mean for Opposite trials (270.9 ms).

The ANOVA revealed a significant main effect of SOA ($F(4, 24) = 93.2$, $p<0.001$). Comparing the overall mean RTs at each SOA, it is evident that as SOA increases, RT decreases (from 338.2 ms at an SOA of 150 ms to 245.5 ms at an SOA of 750 ms). Post-hoc Bonferroni tests revealed significant RT differences between all the SOA vs. all the other SOAs (to at least $p=0.012$) apart from the following 3 SOA pair-wise comparisons: 300 ms vs. 450 ms; 450 ms vs. 600 ms; and 600 ms vs. 750 ms which were not significant.

Table 2.5 Mean RTs (ms) to 'Same' and 'Opposite' side cue trials at 5 SOAs (LED boxes - Same 50%, Opposite 50%)

LED boxes (50%:50%)		Cue side		
		'Same'	'Opposite'	Mean
SOA	150	348.9	327.6	338.2
	300	288.3	274.1	281.2
	450	261.1	265.4	263.3
	600	258.7	246.0	252.4
	750	249.4	241.6	245.5
	Mean	281.3	270.9	276.1

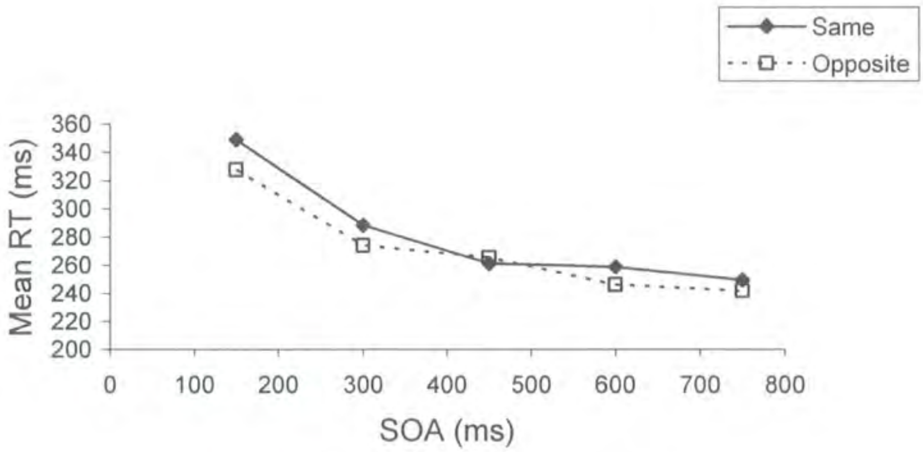


Figure 2.6 LED boxes (50%:50%):
Mean RT to Same and Opposite cued targets

The interaction between 'Cue side' and SOA was not significant ($F(4, 24) = 1.4$, $p=0.265$).

An additional set of ANOVA calculations was also completed to elicit any effects due to learning of the cue-target contingencies: Separate analyses were carried out for the first and third experimental blocks of trials in addition to a comparison between these two blocks.

The pattern of results for the individual blocks was identical to the 'over all blocks' analysis described above:

Block 1 produced significant main effects of 'Cue side' ($F(1,6) = 64.748$, $p<0.001$) and SOA ($F(4, 24) = 110.277$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,24) = 1.340$, $p=0.284$).

Block 3 also showed significant main effects of 'Cue side' ($F(1,6) = 30.824$, $p=0.001$) and SOA ($F(4, 28) = 85.334$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(2.228, 13.367) = 1.677$, $p=0.188$).

There was a significant difference between the two blocks of trials ($F(1, 6) = 6.664$, $p=0.042$). On examination of the data and analysis, it appears that this finding was due to a general decrease in RTs during the course of the experiment, since none of the additional interactions was significant. (i.e. Block x 'Cue side' ($F(1, 6) = 0.734$, $p=0.424$) , Block x SOA ($F(4, 24) = 1.454$, $p=0.247$), Block x 'Cue side' x SOA ($F(4, 24) = 0.430$, $p=0.786$)).

2.6.4 Discussion

As in the previous 4 experiments, there was a significant effect of SOA: as SOA increases, RT decreases. The overall mean times were generally longer than those found in three of the four earlier experiments (RT decreased from 338.2 ms to 245.5 ms), but none of the inter-experimental comparisons reached significance.

The result of the Cue side manipulation was most similar to that found in Experiment 1: overall, the Same side targets were responded to more slowly than the Opposite side targets (although this was not true at the middle 450 ms SOA used). Just as in the previous 4 experiments, the interaction between 'Cue side' and SOA was not present. It appears that the primary effect of the LED boxes was an inhibitory one.

In the Introduction it was suggested that if discrimination were an issue then it was expected that results would be more like those in Experiment 1. Participants did not complain of difficulties in distinguishing between the cue and target. They did however mention problems in detecting the target amongst the constantly illuminated 'corner' LEDs. So, it may be the case that this particular stimulus configuration failed to simulate on-screen conditions due to a perceptual similarity problem and this even though the spatial configuration was closer to that used by Posner and Cohen (1984) and the cue and target were distinguished by colour.

Despite the continued failure to replicate previous exogenous cueing studies, this experiment has perhaps at least resolved an earlier matter. In this experiment there were 9 lights constantly illuminated which could have been potential competitors for an attentional shift (not to mention the 8 cue lights). As in Experiment 1, they did not manage to produce facilitatory shifts of attention, but did bring about an inhibitory effect. So an explanation of competing visual stimuli does not seem appropriate in this case.

2.7 Experiment 6
The effects of informative 'box-like' location cues.

2.7.1 Introduction

In the previous pairs of experiments (i.e. 1 and 2, and 3 and 4) changing the informativeness of the cue affected the results in similar ways. The aim in Experiment 6 was to replicate Experiment 5 with altered cue/target probabilities. The probability of a target occurring on the Same side as the cue was altered to approximately 71% (from 50%) and the probability of an Opposite side target was approximately 29%. If the LED box display 'behaves' comparably, then it might be expected that Same side RTs will be decreased and Opposite side RTs increased in contrast to the results obtained in Experiment 5. A significant effect of SOA should also be found, but no interaction between SOA and Cue side.

2.7.2 Method

Participants

Seven participants (four males and three females) aged between 18 and 29 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates, postgraduates and staff at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus, Stimuli and Design

The apparatus, stimuli and design were as described in Experiment 5.

Procedure

The procedure was identical to that used in Experiment 5 except that the proportion of 'Same' and 'Opposite' trials was altered. Participants were not told about the precise relationship between the cue and target (i.e. that the cue was spatially informative), although they were told that the target would follow the cue with SOAs of 150, 300, 450, 600, or 750 ms.

There were again 140 trials in each of the three blocks giving a total of 420 trials. In this experiment, however, approximately 71% were 'Same' trials (N=300) and approximately 29% were 'Opposite' trials (N=120); each trial type was presented an equal number of times at each of the five SOAs.

2.7.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater than or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the seven participants for 'Same' and 'Opposite' trials at each of the 5 SOAs (i.e. 150, 300, 450, 600, 750 ms). The means are shown in Table 2.6 below.

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and five levels of the second factor: SOA (150, 300, 450, 600, 750 ms).

Looking at the table of means (see Table 2.6) and Figure 2.7 below, four out of five of the 'Same' means (i.e. at each of the SOAs) were smaller than the 'Opposite' means; only the mean RT at 600 ms SOA was slightly longer for the 'Same' than for the 'Opposite' condition; the overall mean RT for Same trials (269.6 ms) was 5.6 ms shorter than the overall mean for Opposite trials (275.2 ms). However, this main effect of the 'Cue side' did not reach significance ($F(1,6) = 0.6$, $p = 0.478$).

Table 2.6 Mean RTs (ms) to 'Same' and 'Opposite' side cue trials at 5 SOAs (LED boxes – Same 71%, Opposite 29%)

LED boxes (71%:29%)		Cue side		
		'Same'	'Opposite'	Mean
SOA	150	320.0	331.7	325.9
	300	278.9	281.6	280.2
	450	255.6	266.7	261.1
	600	254.0	252.1	253.1
	750	239.4	243.9	241.6
	Mean	269.6	275.2	272.4

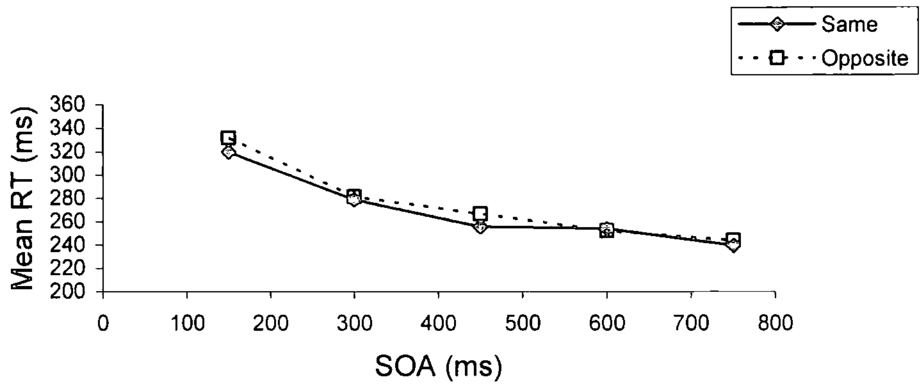


Figure 2.7 LED boxes (71%:29%):
Mean RT to Same and Opposite cued targets

The ANOVA revealed a significant main effect of SOA ($F(1.472, 8.832) = 44.8$, $p<0.001$). Comparing the overall mean RTs at each SOA, it is evident that as SOA increases, RT decreases (from 325.9 ms at an SOA of 150 ms to 241.6 ms at an SOA of 750 ms). All apart from two of the Post-hoc Bonferroni tests revealed significant RT differences (to at least $p=0.024$); only the 450 ms vs. 600 ms and 600 ms vs. 750 ms SOA comparisons were not significant.

The interaction between 'Cue side' and SOA was not significant ($F(4, 24) = 0.9$, $p=0.497$).

An additional set of ANOVA calculations was also completed to elicit any effects due to learning of the cue-target contingencies: Separate analyses were carried out for the first and third experimental blocks of trials in addition to a comparison between these two blocks.

The pattern of results for the individual blocks was identical to the 'over all blocks' analysis described above:

Block 1 produced a non significant main effect of 'Cue side' ($F(1,6) = 6.473$, $p=0.047$), a significant main effect of SOA ($F(1.492, 8.954) = 44.104$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,24) = 0.915$, $p=0.471$).

Block 3 also showed a non significant main effect of 'Cue side' ($F(1,6) = 0.558$, $p=0.483$), a significant main effect of SOA ($F(1.479, 8.871) = 46.142$, $p<0.001$), and a non significant interaction between 'Cue side' and SOA ($F(4,24) = 0.986$, $p=0.434$).

There was a significant difference between the two blocks of trials ($F(1, 6) = 14.327$, $p=0.009$). As in Experiment 5, this appeared to be as a result of a general decrease in RTs during the course of the experiment. None of the interactions with Block was significant. (i.e. Block x 'Cue side' ($F(1, 6) = 2.134$, $p=0.194$) , Block x SOA ($F(1.934, 11.605) = 1.294$, $p=0.084$), Block x 'Cue side' x SOA ($F(4, 24) = 0.194$, $p=0.939$)).

2.7.4 Discussion

As in the previous 5 experiments, there was a significant effect of SOA: as SOA increases, RT decreases. Unlike the other pairs of experiments, the overall mean times with these informative cues were shorter than those found in Experiment 5 where uninformative cueing was in place. There seems no apparent reason why this should be so, except that such variability might be expected across participants. And indeed the difference was not significant.

The results of cue side were similar to those found in Experiment 2: Same side trials were generally facilitated, but this did not reach significance. There was also a non-significant interaction between Cue side and SOA.

Again, as in Experiment 3 and 4, the effects of altering the cue/target contingency brought about a decrease in Same trial means from Experiment 5 to 6, and Opposite trial means have increased. (The same warning note about making cross participant comparisons applies here.)

2.8 General Discussion

All six LED experiments showed significant effects of the SOA manipulation (See Table 2.7 below for summary of results). Whether or not the cue was spatially uninformative (i.e. in Experiments 1, 3, and 5) or informative (i.e. in Experiments 2, 4, and 6) about the appearance of a target, it did provide participants with temporal information. It acted as a warning signal that a response needed to be made - participants were informed that a target would occur within 750 ms - which increases the efficiency of responding. This general finding is in keeping with the original Posner and Cohen (1984) study and indeed with many other experiments in the literature.

In this set of experiments, the Cue side manipulation and Cue side x SOA interaction were initially predicted to reproduce previous findings, but unexpectedly yielded a number of different results.

In Experiments 1 and 2, and in Experiments 5 and 6, participants had some discrimination problems: In Experiments 1 and 2 the cue and target were the same LED in the same location; In Experiments 5 and 6 participants seemed to confuse the constantly illuminated marker LEDs with the target. This resulted in a similar pattern of results (See Table 2.7 for summary of results): When the cue was uninformative (i.e. in Experiments 1 and 5) participants took longer to respond to Same side targets than to Opposite side targets. However, when the cue was informative (i.e. in Experiments 2 and 6) participants tended to respond more quickly to Same side targets, but this result did not reach significance in either experiment. (None of the interactions was significant.) One possible explanation for the differing results due to the increased cue informativeness (i.e. in Experiments 2 and 6) is that the participants' attentional control settings altered throughout the span of the experiment. Although they were not explicitly informed of the cue/target contingencies, participants may have implicitly picked up on these and somehow altered their behaviour. It is unclear what precise mechanism would enable participants to do this, but such alterations have been reported in the literature (e.g. Folk, Remington & Johnston, 1992; Folk, Remington & Wright, 1994; see also Yantis, 1998).

Table 2.7 Summary of results for the 6 LED experiments (i.e. Experiments 1-6)

	SOA	'Cue side'	Interaction Same/Opp x SOA
Expt 1 Same light (50%:50%)	sig	sig (Same>Opp)	ns
Expt 2 Same light (71%:29%)	sig	ns (Same<Opp)	ns
Expt 3 Cue: Near; Target: Far (50%:50%)	sig	ns (Same<Opp)	ns
Expt 4 Cue: Near; Target: Far (71%:29%)	sig	sig (Same<Opp)	ns
Expt 5 LED boxes (50%:50%)	sig	sig (Same>Opp)	ns
Expt 6 LED boxes (71%:29%)	sig	ns (Same<Opp)	ns

In Experiments 3 and 4, where there were no problems in discriminating the cue from the target, participants responded to Same side targets more speedily than Opposite side targets across all SOAs. (Again, neither of the interactions of Cue side with SOA was significant.) The cue/target probability manipulation appeared to enhance the finding so that although there was a non-significant finding in Experiment 3, this was significant in Experiment 4. This result would support the notion that explanations of inhibition of return (IOR) may not be based on sensory stimulation.

To recap briefly on IOR: In Posner and Cohen's (1984) experiment, targets appearing at cued locations were initially responded to more quickly (facilitation), but at longer cue-target SOAs detection times were slowed. One view is that attention moves away from the cued location and inhibition is directed at it. If a response is then required to a target at that cued location, inhibition would have to be overcome with resulting longer RTs. Effectively this would produce a mechanism reflecting a bias towards novel stimuli, or a bias against already attended locations (This would make intuitive sense in evolutionary terms as an adaptive search process (Klein, 1988), but there seems to have been little success in linking search with IOR (see Klein & Taylor, 1994; Wolfe & Pokorny, 1990)). This account of inhibition is one that focuses on attention.

Alternative explanations have focussed on sensory stimulation. For example Berlucchi, Chelazzi, & Tassinari (2000) suggest that it is not moving and engaging attention that takes up the time, but that once attention has moved from the cued location, sensory processing at that location is inhibited and therefore responding to targets will be slower. The results from Experiment 4 (though similar trends are found in Experiments 2, 3, and 6) seem to contradict this since no inhibition has been found.

Another alternative explanation that could account for the results is that of oculomotor programming (Rafal, Calabresi, Brennan, & Sciolto (1989); Taylor &

Klein, 1998). Evidence suggests if an eye movement is planned in response to either an exogenous or endogenous central cue then IOR is observed whether or not the eye movement is executed. In the LED experiments described here which do not find IOR, then perhaps this is due to a resultant lack of activation of the oculomotor system.

Overall, although these LED experiments have led to some interesting results, they did not yield a suitable procedure with which to pursue easily the intended issues of grouping using exogenous and endogenous cueing. The following chapter introduces a different methodology and looks more closely at the topic of IOR.

Chapter 3

The effects of large and small static displays, and present and absent cue-markers on the components of visual orienting.

3.1 General Introduction

The following chapter includes four experiments designed to resolve the discrepant findings reported in the previous chapter. Participants were asked to respond with a key press as quickly as possible to a target following a luminance increment cue. The experiments manipulated the size of attentional focus and presence of a peripheral cue marker in an attempt to reproduce previous exogenous cueing findings and investigate further the nature of components of visual orienting, and in particular that of inhibition of return (IOR).

In the last chapter research using LEDs failed to produce the customary results of exogenous cueing experiments. The first experiment (Experiment 7) attempted to remedy this by using a similar methodology to that of Posner and Cohen (1984) where three 1^0 square boxes 2.5^0 apart were displayed horizontally on a computer screen. The middle square contained a centred fixation point, which, along with the boxes, remained visible throughout the experiment. A brightening of the left or right box acted as a cue to a target which could appear following the cue with equal probability within the cued box (a Same side trial) or within the uncued box (an Opposite side trial). Unlike Posner and Cohen's study, there were no central box targets, but in this experiment (and in Experiments 8, 9 and 10) catch trials were included.

In many experiments using exogenous cueing techniques, responses to targets at cued locations are initially speeded relative to those at uncued locations, but when the time between cue and target is increased (to 300 ms and above) responses to cued targets are slowed. This phenomenon is referred to as inhibition of return (IOR). Tipper and his co-workers (e.g. Jordan & Tipper, 1998; Tipper, Driver & Weaver, 1991; Tipper, Weaver, Jerreat, & Burak, 1994) using dynamic displays, have suggested that this IOR is made up of two separate components, a location-based and an object-based component, which together add to produce and overall IOR effect. To investigate this further, Experiment 8 used an identical methodology to Experiment 7, except that only the central fixation box was visible throughout. There were no cue-markers (left and right boxes) visible. The cues, as in Experiment 7, were a 'brightening', or rather an appearance, of either the left or right box. According to the dual component model of IOR, the absence of the cue-marker should only result in a reduced amount of inhibition.

A number of studies have explored the spatial distribution of attention. The zoom lens account of attention (discussed in Chapter 1 section 1.3.2) would suggest that as the size of attentional focus increases the efficiency of processing information should decrease. And conversely, if the size decreases, then efficiency should increase (although other accounts would not make this prediction). To examine this (and to use the results of this experiment to aid design and interpretation of later planned work) Experiment 9 used an experimental procedure that was identical to Experiment 7, except that the size of the boxes was reduced to $1/3^0$ square.

Experiment 10 used the same procedure as Experiment 8, except that the size of the central fixation and cue boxes were, as in Experiment 9, reduced to $1/3^0$ square. The expectation here is that the absence of cue-markers, as in Experiment 8, should produce a reduction in IOR, whereas the size of attentional focus might predict generally more efficient processing.

3.2 Experiment 7

The effects of a 'large' display and present cue-markers on the components of visual orienting.

3.2.1 Introduction

The main aim of this experiment was to reproduce the usual exogenous peripheral cueing results found in many published studies and thence to act as a 'baseline' comparison to the three other experiments which altered some of the stimulus properties. As already mentioned in the General Introduction to this chapter, the methodology used was similar to that of Posner and Cohen (1984) but with certain adaptations. As in their original study, here three boxes were displayed with a central fixation visible during the entire experiment. A brightening of one of the boxes (the cue) sought to draw the participant's attention from the centre (though participants were instructed to maintain fixation throughout) to the near periphery (only 2.5^0 from fixation). Following a variable SOA, a target appeared either in the Same brightened box (a Same trial), or in the box on the other side of fixation (an Opposite trial) to which the participant was asked to respond as quickly as possible. The probability of Same side trials and Opposite side trials was equal, but a number of catch trials where no target appeared was also included. It was predicted that despite the spatial uninformativeness of the cue (i.e. knowing where the cue occurred did not help in predicting the location of the target), reaction times would be initially be faster for targets occurring on the Same side as the cue as compared to those on the Opposite side showing a facilitatory effect, but then at later cue-target intervals reaction times would be slowed, showing an inhibition of return effect.

Specifically in terms of the experiment these reaction time differences should elicit a significant interaction effect between SOA and cue side. A main effect of SOA should also be evident such that as time between cue and target onset increased, reaction time would generally decrease. Depending on the relative size of the facilitatory and inhibitory effects, a main effect of Cue side may or may not be evident.

3.2.2 Method

Participants

Ten participants (six males and four females) aged between 18 and 36 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates, postgraduates and staff at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh Performa 630 with stimuli presented on an Apple MultipleScan 1705 Display screen. The keyboard space bar was used as the response key.

Participants positioned their chin on a rest to limit head movements throughout the session. This was fixed to produce a 57cm viewing distance aligned with the central fixation point.

Stimuli

The stimuli used in this experiment were three 1^0 square boxes, centred on the screen, 1.5^0 apart (i.e. 2.5^0 from the centre of one box to the next). The middle box contained a centred fixation point and this, along with the three boxes, remained present throughout the experiment. The cue was a brightening of the left or the right box. The target for response was a $1/3^0$ cross appearing in the centre of one of the peripheral boxes.

Design

The design was a within-subjects design with 2 independent variables: Cue side (2 levels: Same, Opposite) and SOA (3 levels: 100, 300, 500 ms). The dependent variable was the mean response time to detect a target.

Procedure

The participant was seated in front of the screen and the chin rest adjusted so that the participant's eyes were level with the central fixation point. The procedural instructions were given verbally and any questions about the task were answered.

A key press initiated the start of the experiment. The three boxes and fixation point then appeared on the screen for 5 seconds to enable the participant to easily fixate the central spot. The block of trials then began with the first 100 ms cue, a brightening of one of the boxes to the left or to the right. Following an SOA of 100, 300, or 500 ms, a target cross appeared either in the centre of the box on the same side as the cue ('Same' trials), or in the box on the opposite side to the cue ('Opposite' trials). The target remained visible until the participant responded with a single key press indicating that they had detected the target. Participants were asked not to move their eyes throughout the entirety of the experiment, but to keep them positioned on the central fixation spot. After a variable inter-trial interval

(ITIs = 400, 500, 600, 700, 800, or 900 ms) the next trial began with another peripheral cue flash.

The task was always one of a simple reaction time, that is, a single key press to the onset of a visual target. The reaction-time key was placed to enable ease of response with the index finger by the participant's preferred hand, and this key was also used to initiate the first trial in each block. The room lights were extinguished. The participant was given a number of practice trials to familiarise them with the situation before starting the experiment proper.

Following the end of the experimental session the participants were debriefed and any questions about the experiment answered.

There were 84 trials in each block; made up of 72 experimental trials and 12 catch trials randomly presented throughout the block. A catch trial consisted of a cue followed by no target, plus the variable ITI time. There were therefore a total of 252 trials: 216 experimental trials and 36 catch trials. Half of the trials were 'Same' and half were 'Opposite' with a third of each of these at each of the three SOAs. Half of the trials involved a right side box cue flash, and half a left side box cue flash.

3.2.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater then or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the 10 participants for 'Same' and 'Opposite' trials at each of the 3 SOAs (i.e. 100, 300, 500 ms). The means are shown in Table 3.1 below.

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and three levels of the second factor: SOA (100, 300, 500 ms).

As is apparent from the table of means (see Table 3.1) the ANOVA produced a non significant main effect of the 'Cue side' manipulation ($F(1,9) = 0.003$, $p=0.959$). The overall mean for Same trials (326.0 ms) was very similar to the overall mean for Opposite trials (326.2 ms).

Table 3.1 Mean RTs to 'Same' and 'Opposite' side cue trials at 3 SOAs; Large boxes present

		Cue side			
		'Same'	'Opposite'	Mean	Same-Opp
SOA	100	341.2	359.1	350.2	-17.9
	300	312.1	313.3	312.7	-1.2
	500	324.6	306.1	315.4	18.5
	Mean	326.0	326.2	326.1	-0.2

A significant main effect of SOA was found ($F(2,18) = 36.3$, $p<0.001$). The optimum SOA in this experiment was 300 ms which resulted in an overall mean RT of 312.7 ms, as opposed to a mean RT of 315.4 ms at SOAs of 500 ms, and the slowest mean RT of 350.2 ms at 100 ms SOA. Pairwise comparisons revealed significant differences between SOAs of 100 ms and 300 ms ($p<0.001$), and 100 ms and 500 ms ($p=0.001$), but a non-significant difference between 300 and 500 ms SOAs ($p=1.000$).

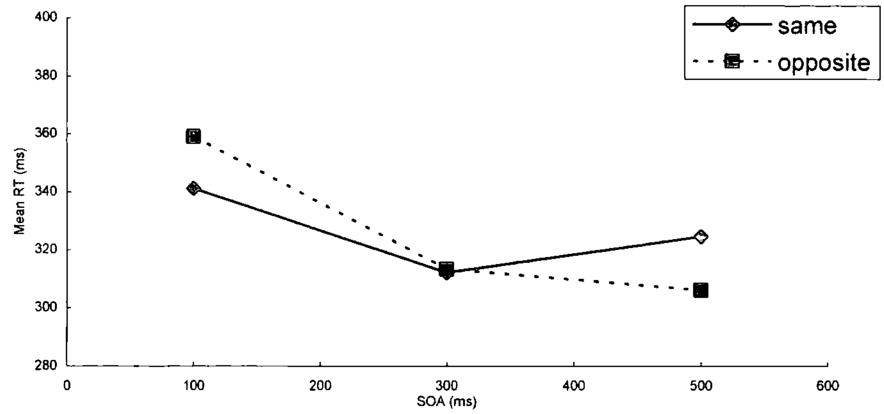


Figure 3.1 Mean RT to Same and Opposite Cued Targets at 3 SOAs

The interaction between 'Cue side' and SOA was significant ($F(2,18) = 13.760$, $p<0.001$). (See Figure 3.1.) At the shortest SOAs Same side targets were detected faster than Opposite side targets (Mean Same - Opposite difference = -17.9 ms); at 300 ms SOAs there was no real difference between RTs (Mean Same-Opposite difference = -1.2 ms); whilst at the longest SOAs, Same side targets were slower to be detected than Opposite side targets (Mean Same-Opposite difference = 18.5 ms).

3.2.4 Discussion

Varying the onset time between the cue and the target in this experiment produced the customary finding. Although the cue was spatially uninformative about the location of the subsequent target, it did give the participants some temporal information so that as the SOA increased response times to targets generally decreased.

The main effect of Cue side was not significant. However this was not as a consequence of no differences between the Same side and Opposite side conditions since there was a significant interaction effect between Cue side and SOA. As in many earlier experiments the results here demonstrated a speeding of RTs to Same side targets relative to Opposite side targets at the two shorter SOAs (a facilitation of 17.9 ms at 100 ms SOA), and a slowing of RTs at longer SOAs (an inhibition of 18.5 ms).

The fact that these facilitatory and, more importantly, inhibitory effects were produced is interesting given the slight alterations to the design. The majority of studies have used some cue probability manipulation or a flashing of the central fixation after a peripheral luminance change to 'draw participant's attention back to fixation'. Despite the fact that neither of these strategies was included in this experiment sizeable (and comparable to those found in earlier work) inhibitory effects were elicited.

3.3 Experiment 8

The effects of a 'large' display and absence of cue-markers on the components of visual orienting.

3.3.1 Introduction

Posner and his colleagues in the 80's (e.g. Posner, 1980) proposed that attention acts as a spotlight illuminating and enhancing processing in areas of mental space. However, a wealth of evidence has now been produced against a purely spatial account which suggests that covert attention may operate on more structured forms such as objects or object segments (e.g. Cole, Gellatly, & Blurton, 2001; Driver & Baylis, 1989; Duncan, 1984; Gellatly & Cole, 2000; Kahneman & Henik, 1981). In order to distinguish between these object-based and location-based views it is necessary to show that attention has been directed to an object (or at least part of an object) and not to a position in space. One way of doing this has been to use displays which incorporate moving objects. (See Chapter 1 for a more detailed discussion on object- vs. location-based accounts.) Tipper, Driver & Weaver (1991) presented two boxes either side of fixation which, following the brightening of one of them on one side, rotated 180^0 to take up the position of the opposite box location. As a result of this procedure, they found inhibition at the new location of the previously cued object and not of the previously cued location. This methodology was extended to using four boxes which were rotated by 90^0 (Tipper, Weaver, Jerreat, & Burak, 1994) and on the basis of these results they concluded that IOR has both an object-based component and a location-based component which Jordan & Tipper (1998) suggested were additive. If this is indeed the case, then static displays should produce larger amounts of IOR than dynamic displays since the former will be the sum of both object- and location- based IOR, whereas the latter will only elicit object-based IOR. The majority of static displays have used boxes or other markers to indicate the possible location of cues and targets. The question posed in Experiment 8 is what level of IOR is found in a static display in the absence of such location markers?

Experiment 8 used an identical methodology to Experiment 7, except that only the central fixation and fixation box were visible throughout. The cue-markers (left and right boxes) were never visible. The cues, as in Experiment 7, were a 'brightening', or rather an appearance, of either the left or right box which was followed after a variable SOA by the appearance of a target in either the Same or Opposite location as the box-cue flash. According to the dual component model of IOR, the absence of the cue-marker should produce only a small amount of inhibition since in this case only location-based IOR should be evident.

In terms of the experiment, one would predict the usual SOA finding where increasing SOAs produces decreasing response times. An interaction between SOA and Cue side should also be expected, but in comparison to Experiment 7, the amount of inhibition would be reduced. Again, a main effect of Cue side may or may not be evident depending on the relative magnitude of facilitatory and inhibitory effects.

3.3.2 Method

Participants

Ten participants (six males and four females) aged between 18 and 30 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates, postgraduates and staff at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh Performa 630 with stimuli presented on an Apple MultipleScan 1705 Display screen. The keyboard space bar was used as the response key.

Participants positioned their chin on a rest to limit head movements throughout the session. This was fixed to produce a 57cm viewing distance aligned with the central fixation point.

Stimuli

The stimuli used in this experiment were identical to those used in Experiment 7: three 1^0 square boxes, centred on the screen, 1.5^0 apart. The middle box contained a centred fixation point and this remained present throughout the experiment. Unlike Experiment 7 however, the two boxes to the left and to the right of centre were not present throughout.

The cue was a 'brightening' of the left or the right box. The target for response was a $1/3^0$ cross appearing in the centre of one of the peripheral boxes.

Design

The design was a within-subjects design with 2 independent variables: Cue side (2 levels: Same, Opposite) and SOA (3 levels: 100, 300, 500 ms). The dependent variable was the mean response time to detect a target.

Procedure

The procedure was identical to that used in Experiment 7 except that, following the initial key press to start the experiment, only the fixation point and central box appeared on the screen for the first 5 seconds. The block of trials began with the first 100 ms cue, a 'brightening' of one of the boxes to the left or to the right. In essence the brightening was an appearance of a box for 100 ms indicating the possible location of a target cross appearing after an SOA of 100, 300, or 500 ms.

Otherwise, the procedure and organisation (e.g. 84 trials in each of three bocks) of the experiment was the same as that used in Experiment 7.

3.3.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater then or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the 10 participants for 'Same' and 'Opposite' trials at each of the 3 SOAs (i.e. 100, 300, 500 ms). The means are shown in Table 3.2 below

Table 3.2 Mean RTs to 'Same' and 'Opposite' side cue trials at 3 SOAs; Large boxes absent

		Cue side			
		'Same'	'Opposite'	Mean	Same-Opp
SOA	100	341.8	346.9	344.4	-5.1
	300	320.0	304.0	312.0	16
	500	338.1	298.2	318.2	39.9
	Mean	333.3	316.4	324.8	16.9

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and three levels of the second factor: SOA (100, 300, 500 ms).

There was a significant main effect of the 'Cue side' ($F(1,9) = 23.8$, $p=0.001$). The Same trials (overall RT mean = 333.3 ms) produced significantly longer response times than the Opposite trials (overall RT mean = 316.4 ms).

There was also a significant main effect of SOA ($F(2,18) = 9.3$, $p=0.002$). Fastest RTs were produced at SOAs of 300 ms (overall mean = 312.0 ms), intermediate RTs were found at SOAs of 500 ms (overall mean = 318.2 ms), and the slowest RTs for SOAs of 100 ms (overall mean = 344.4 ms), Pairwise comparisons revealed a significant difference between SOAs of 100 ms and 300 ms ($p=0.007$), but no significant differences between SOAs of 100 ms and 500 ms ($p=0.055$), and SOAs of 300 and 500 ms ($p=1.000$).

The interaction between 'Cue side' and SOA was also significant ($F(2,18) = 20.5$, $p<0.001$). (See Figure 3.2.) At the shortest SOA of 100 ms, Same side targets were detected slightly faster than Opposite side targets (Mean Same-Opposite difference = -5.1 ms); at 300 ms SOA, Same side targets were slower to be detected than Opposite side targets (Mean Same-Opposite difference = 16 ms); and even slower at an SOA of 500 ms (Mean Same-Opposite difference = 39.9 ms).

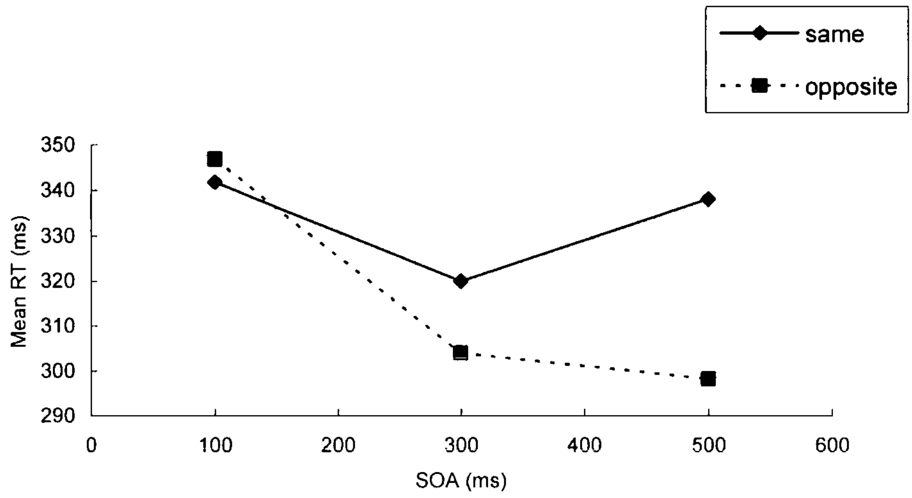


Figure 3.2 Mean RT to Same and Opposite Cued Targets at 3 SOAs

3.3.4 Discussion

As in Experiment 7, the results here also show an effect of the SOA manipulation: reaction times to targets initially decreased with increasing SOA, and then increased slightly at the longest SOA.

Unlike Experiment 7 however, there was an effect of the Cue side such that, in general, Same side trials produced significantly *longer* response times than Opposite side trials. This was coupled with a significant interaction between SOA and Cue side. Facilitation of RTs to Same side targets relative to Opposite side targets was found at the earliest SOA (100 ms) and an inhibition of RTs was found at the two later SOAs.

In comparison to Experiment 7, the amount of facilitation produced in this experiment was reduced from a mean of 17.9 ms to 5.1 ms at an SOA of 100 ms. (However, the overall post hoc comparison between the experiments revealed no significant difference.) It seems that the absence of a cue-marker may have brought about a change in the effectiveness of the cue. Perhaps the lack of a well-defined location for attention has caused a reduction in the focus of attention. Zoom lens proponents would predict this inverse relationship between size of the attentional focus and magnitude of effect. Hoffman and Mueller (1994), commenting on the distinction between real-world and computer-generated simulations of depth, noted that what is crucial is the presence of placeholder objects marking the positions of the to-be-attended location. In the absence of these it was not possible to direct attention in 3D, so perhaps this experiment also provides evidence for a reduced ability to direct attention without placeholder information in two-dimensional displays.

Unlike the level of facilitation, the level of inhibition has increased from Experiment 7 to Experiment 8 from 18.5 ms to 39.9 ms at an SOA of 500 ms. This is not consistent with the prediction made in the Introduction. According to the dual component view, resultant IOR is a combination of object-based and location-based inhibition and since Experiment 8 omitted the cue-marker (i.e. only location-based information available shortly before the target and no object-based, or placeholder, information included) the results should have seen a reduction in the amount of IOR.

Since the completion of this experiment, a number of investigators have presented studies looking at IOR in static displays. The results of these studies appear contradictory. For example, McAuliffe, Pratt, and O'Donnell (2001) also failed to show additive effects. They instead propose a single-component IOR mechanism where objects and locations are treated differently. Such a mechanism, they say, requires three assumptions: firstly, that "there is an upper limit to the amount of IOR that can be applied to any given object or location"; secondly, "that a cued location will get as much inhibition as is possible at that moment"; and thirdly when involved in visual search, "people are more likely to orient their attention toward an object in the visual field than in an empty space" (p1080). On the basis of these assumptions, maximal IOR will be found when there are only objects or locations in a display, but when both objects and locations are present IOR is more likely to be directed to objects rather than towards an empty space. These assumptions together would not account for the findings in Experiment 8 since both objects (the fixation box) and locations (the cued area) were present and levels of IOR were greater than in Experiment 7. (No measure of IOR to the central box was taken in Experiments 7 or 8, so comparisons to the previous experiment are the only ones possible here.)

(As an adjunct to the Discussion of Experiment 7, McAuliffe, Pratt, and O'Donnell (2001) also investigated the role of the fixation cue and concluded that researchers "should not be concerned with the presence or absence of fixation cues...given sufficient time...[long enough SOAs]...designs using or not using fixation cues produce equivalent IOR effects." (p1081))

Contrary to McAuliffe, Pratt, and O'Donnell (2001), Leek, Reppa, and Tipper (2003) (and also Jordan & Tipper, 1998) present results that are consistent with the dual component IOR view. Leek et al (2003) manipulated object present and object absent (as well whether an object was segmented or not). They found significantly larger IOR in object present than object absent displays. Furthermore they found that IOR was influenced by the internal structure of objects – an issue that will be returned to at a later time.

Although these studies contradict each other, neither help explain the finding of an increase in IOR in the present experiment. So what then may account for the relatively large IOR found here?

One very simple fundamental difference between this experiment and those mentioned above is that this study only looked at relatively short SOAs (up to 500 ms). Perhaps if longer cue-target onset times had been investigated similar differences in IOR may have been found. However the patterning of results found does not indicate a downward trend for IOR, rather the reverse.

Another possibility is that the luminance change in Experiment 8 was greater than that in Experiment 7 producing a greater level of inhibition. Indeed, it is known that abrupt visual onsets do indeed capture attention (e.g. Gellatly, Cole, & Blurton, 1999; Todd & Van Gelder, 1979; Yantis & Jonides, 1984) and Houghton and Tipper (1994) note that levels of inhibitory feedback are affected by stimulus intensity. However, conversely, it has also been shown that decreases in luminance also capture attention, and that luminance increments are not necessary to capture visual attention (Yantis & Hillstrom, 1994).

Perhaps, what is more important here are the assumptions underlying levels of excitation and inhibition. One approach is to suppose that following a cue (such as a luminance change), there is an initial period of excitation which arises and then falls to zero, followed by a period of inhibition. Calculating a RT at any one moment can then be seen as measuring just one of these mechanisms. If this holds true, then one possibility is that the box flash in Experiment 8 generated both a location-based IOR and also created an object-based IOR that, when measured, summed to an overall greater IOR than caused by the stimuli in Experiment 7.

However, Tipper, Rafal, Reuter-Lorenz, Starrveldt, Ro, Egly, Danziger, and Weaver (1997) suggest an alternative view: excitation and inhibition associated with object-based representations are thought to be mediated by different neural structures and as a consequence coexist, with resulting RT effects being a sum of both components. If the appearance of an object had no effect on levels of inhibition, but did affect levels of excitation, then removing the box, or perception of an object, in Experiment 8 would result in reduced levels of excitation and would result in an apparent increase in levels of inhibition (when compared with Experiment 7 when an object was present and levels of excitation plus inhibition summed to a smaller overall value).

It is therefore difficult to make any firm conclusions about the nature of object-based IOR simply on the basis of these results.

3.4 Experiment 9

The effects of a 'small' display and present cue-markers on the components of visual orienting.

3.4.1 Introduction

As mentioned in the General Introduction to this chapter, a number of studies have explored the spatial distribution of attention. A burgeoning of work in the late 70's and early 80's brought about a number of possibilities. Posner and his colleagues proposed a metaphor which involved a specific sized attentional spotlight which moved in an analogue fashion from one location to another. Jonides (1983) suggested that attention could either be evenly distributed across a display or be focused. The former mode of attending would enable parallel processing of information, whilst the latter mode would produce enhanced processing of attended elements and worsened processing of other elements. Several earlier studies (e.g. Beck & Ambler, 1973; Egeth, 1977) had also already found a reciprocal relationship between the size of a focus of attention, which could be varied, and discrimination accuracy and processing time benefits. A different metaphor was developed which likened attention to a variable-sized zoom lens (Eriksen & St. James, 1986; Eriksen & Yeh, 1985). LaBerge (1983) and LaBerge and Brown (1986) also supported this idea and concluded that attentional focus size could vary, for example, with task demands, but did not find that processing speeds increased with the narrowing of the attentional focus. A more recent study by Castiello & Umiltà (1990) has also suggested that the size of attentional focus could be adjusted to encompass different sized areas of the visual field, but like the earlier studies by Egeth (1977) and others, did find a decrease in processing efficiency with increasing focus.

So, it is apparent that it is possible for people to attend to locations in space and to vary the size of the attentional beam in response to the task demands. The majority of evidence implies that as the size of the attentional focus increases then processing abilities decrease.

Although the emphasis in current research has shifted away from trying to measure the spatial distribution of attention in 2D space (as is evidenced by the paucity of recent publications) and has focused more on object-based descriptions, nevertheless, given the rather mixed results of Experiments 1-6 using LEDs, Experiment 9 presents an exogenous cueing task similar to that of Experiment 7 except that the size of the boxes was reduced to $1/3^0$ square making the discriminability of the $1/3^0$ cross target difficult. If it is possible to narrow the focus of attention within the time limits of this task, then the pattern of results should be similar to that of Experiment 7, with comparable facilitatory and inhibitory components emerging from the data. If the focusing of attention is such that it allows for generally enhanced performance, then one might predict that overall RTs are faster here than in Experiment 7. Alternatively, if the reduced box size makes cue-target discrimination more difficult, then overall slower RTs might be expected.

So, in terms of the experimental variables, the standard main effect of SOA should be expected where increasing SOAs will be associated with decreasing response times; an interaction between SOA and Cue side would also be predicted following a similar pattern to that found in Experiment 7 and, if results are similar to Experiment 7, then one would also predict a non-significant Main effect of the Cue side manipulation.

3.4.2 Method

Participants

Ten participants (five males and five females) aged between 18 and 22 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates and postgraduates at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh Performa 630 with stimuli presented on an

Apple MultipleScan 1705 Display screen. The keyboard space bar was used as the response key.

Participants positioned their chin on a rest to limit head movements throughout the session. This was fixed to produce a 57cm viewing distance aligned with the central fixation point.

Stimuli

The stimuli used in this experiment were similar to those used in Experiment 7 except that the size of the square boxes was reduced to $1/3^0$. Again, three square boxes were centred on the screen, with 2.5^0 from the heart of one box to the next. The middle box contained a centred fixation point and this, along with the three boxes, remained present throughout the experiment. The cue was a brightening of the left or the right box. The target for response was a $1/3^0$ cross appearing in the centre of one of the peripheral boxes.

Design

The design was a within-subjects design with 2 independent variables: Cue side (2 levels: Same, Opposite) and SOA (3 levels: 100, 300, 500 ms). The dependent variable was the mean response time to detect a target.

Procedure

Apart from the change in box size, the procedure and other experimental details were identical to those used in Experiment 7.

3.4.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater then or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the 10 participants for 'Same' and 'Opposite' trials at each of the 3 SOAs (i.e. 100, 300, 500 ms). The means are shown in Table 3.3 below

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and three levels of the second factor: SOA (100, 300, 500 ms).

Table 3.3 Mean RTs to 'Same' and 'Opposite' side cue trials at 3 SOAs; Small boxes present

		Cue side			
		'Same'	'Opposite'	Mean	Same-Opp
SOA	100	438.8	447.0	442.9	-8.2
	300	391.2	399.3	395.3	-8.1
	500	396.9	406.0	401.5	-9.1
	Mean	409.0	417.4	413.2	-8.4

The ANOVA produced a non significant main effect of 'Cue side' (F(1,9) = 1.4, p=0.271). The overall mean for Same trials (409.0 ms) was smaller, but not significantly so, than the overall mean for Opposite trials (417.4 ms).

There was a significant main effect of SOA (F(2,18) = 21.7, p<0.001). Fastest RTs were produced at SOAs of 300 ms (overall mean = 395.3 ms), intermediate RTs were found at SOAs of 500 ms (overall mean = 401.5 ms), and the slowest RTs for SOAs of 100 ms (overall mean = 442.9 ms). Pairwise comparisons revealed significant differences between SOAs of 100 ms and 300 ms (p<0.001), and 100 ms and 500 ms (p=0.008), but a non-significant difference between 300 and 500 ms SOAs (p=1.000).

As is apparent from the graph below ((See Figure 3.3) the interaction between 'Cue side' and SOA was not significant (F(1.197, 10.769) = 0.002, p = 0.979).

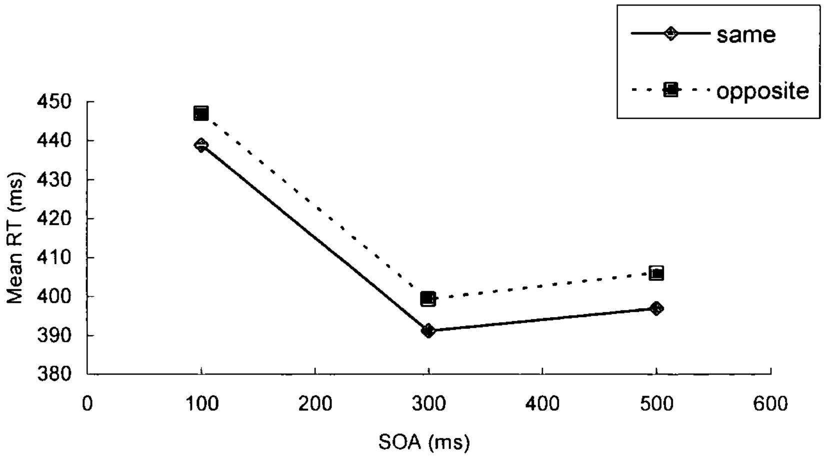


Figure 3.3 Mean RT to Same and Opposite Cued Targets at 3 SOAs

3.4.4 Discussion

As in all the earlier experiments, the results of Experiment 9 show an effect of the SOA manipulation: reaction times to targets decreased with increasing SOA.

In terms of the Cue side main effect and Cue side x SOA interaction, it was predicted that these would also produce similar results to those of Experiment 7. Although the Cue side main effect was not significant here, it is apparent that the pattern of results which produced this was not the same as that in Experiment 7 and this is also indicated by the non significant interaction. Reaction times to Same side targets appear to be smaller than those to Opposite side targets, but as already mentioned above, this was not a significant finding. The measures of facilitation and inhibition are also small and unlike those found in Experiment 7.

Like the participants in Experiments 1, 2, 5, and 6, people who were involved in this study complained of the discrimination problems of the task. They were not able to use a narrowed or enhanced processing focus of attention to facilitate their responding; the task was simply too difficult to show differences between RTs to Same and Opposite side targets. And indeed, comparing the general level of reaction times (bearing in mind that these may vary enormously across participants) rather than being speeded in this experiment relative to those of Experiment 7, they are markedly slowed. (The post hoc comparisons revealed significant RT differences between Experiment 9 and Experiments 7 and 8.)

Finally, this experiment used only relatively short SOAs. If longer Cue-target onset times had been investigated a pattern of results similar to that of Experiment 7 may have been reported. If one takes the view that rather than being a study looking at detection, this experiment was more like a discrimination task, then there is evidence to suggest that looking at longer SOAs may have demonstrated an IOR effect (e.g. Lupiáñez, Milán, Tornay, Madrid, Tudela, 1997). Also, Lupiáñez, Milliken, Solano, Weaver, and Tipper (2001) who compared discrimination and detection tasks using an exogenous cueing paradigm, noted that this later emergence of IOR in discrimination tasks as compared to detection tasks was related to perceptual discrimination and not due to response selection differences between discrimination and detection tasks.

3.5 Experiment 10

The effects of a 'small' display and absence of cue-markers on the components of visual orienting.

3.5.1 Introduction

The final experiment in this chapter completed the sequence of large or small cue and target location boxes being present or absent. Experiment 10 followed the same procedure as in previous experiments. The size of the central fixation box was, as in Experiment 9, a $1/3^0$ square. The cue-marker boxes which were present in Experiment 9 were absent here and only appeared briefly illuminated acting as the cue before the onset of a $1/3^0$ target.

If the dual component model of IOR holds true with this particular static display, then the absence of cue-markers should produce a reduction in IOR. (Although due to the results of Experiment 9, it is difficult to know what would be an appropriate comparison.) If, however, the results follow the same pattern as that found in Experiment 8, one would predict an increased level of inhibition. In addition to this, the decrease in the size of attentional focus might bring about an enhancement in processing.

In terms of the experimental variables, the SOA manipulation should show a significant reduction in RTs with increasing cue/target onset time. There should also be a significant interaction between Cue side and SOA, but in comparison to

Experiment 9 (?) the size of IOR should be reduced. A main effect of Cue side may again be apparent perhaps depending on the balance between facilitatory and inhibitory effects.

3.5.2 Method

Participants

Ten participants (four males and six females) aged between 18 and 25 years took part in the three blocks of trials making up the experiment.

The participants were undergraduates and postgraduates at the University of Durham. All were volunteers and were paid at a rate of £3.00 per hour.

All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh Performa 630 with stimuli presented on an Apple MultipleScan 1705 Display screen. The keyboard space bar was used as the response key.

Participants positioned their chin on a rest to limit head movements throughout the session. This was fixed to produce a 57cm viewing distance aligned with the central fixation point.

Stimuli

The stimuli used in this experiment were identical to those used in Experiment 9: three $1/3^0$ square boxes. The middle box contained a centred fixation point and this remained present throughout the experiment. Unlike Experiment 9 and like Experiment 8, the other two boxes to the left and to the right of centre were not present throughout.

The cue was a 'brightening' of the left or the right box. The target for response was a $1/3^0$ cross appearing in the centre of one of the peripheral boxes.

Design

The design was a within-subjects design with 2 independent variables: Cue side (2 levels: Same, Opposite) and SOA (3 levels: 100, 300, 500 ms). The dependent variable was the mean response time to detect a target.

Procedure

The procedure was identical to that used in Experiment 8: following the initial key press to start the experiment, only the fixation point and central box appeared on the screen for the first 5 seconds. The block of trials began with the first cue, a 100 ms 'brightening'/appearance of one of the boxes to the left or to the right indicating the possible location of a target cross appearing after an SOA of 100, 300, or 500 ms.

3.5.3 Results

Response times less than or equal to 100 ms were discarded from the analyses as these were regarded an anticipations. Responses greater then or equal to 700 ms were treated as non responses, or lapses of concentration, and were also discarded from analyses.

The mean RTs were calculated for each of the 10 participants for 'Same' and 'Opposite' trials at each of the 3 SOAs (i.e. 100, 300, 500 ms). The means are shown in Table 3.4 below

A two factor repeated measures ANOVA was performed with two levels of the first factor: Cue side (Same, Opposite); and three levels of the second factor: SOA (100, 300, 500 ms).

Table 3.4 Mean RTs to 'Same' and 'Opposite' side cue trials at 3 SOAs; Small boxes absent

		Cue side			
		'Same'	'Opposite'	Mean	Same-Opp
SOA	100	387.6	372.3	380.0	15.3
	300	338.5	327.9	333.2	10.6
	500	362.1	322.0	342.1	40.1
	Mean	362.7	340.7	351.7	22

There was a significant main effect of the 'Cue side' ($F(1,9) = 7.4$, $p=0.024$). The Same trials (overall RT mean = 362.7 ms) produced significantly longer response times than the Opposite trials (overall RT mean = 340.7 ms).

There was also a significant main effect of SOA ($F(2,18) = 30.8$, $p<0.001$). Fastest RTs were produced at SOAs of 300 ms (overall mean = 333.2 ms), intermediate RTs were found at SOAs of 500 ms (overall mean = 342.1 ms), and the slowest RTs for SOAs of 100 ms (overall mean = 380.0 ms). Pairwise comparisons revealed significant differences between SOAs of 100 ms and 300 ms ($p<0.001$), and 100 ms and 500 ms ($p=0.002$), but a non-significant difference between 300 and 500 ms SOAs ($p=0.088$).

The interaction between 'Cue side' and SOA was also significant ($F(2,18) = 5.3$, $p=0.015$). (See Figure 3.4.) At 100 ms and 300 ms SOAs, Same side RTs to targets were slower than RTs to Opposite side targets (Mean RT differences were 15.3 ms and 10.6 ms respectively); at 500 ms SOAs this Same-Opposite side RT difference was even greater (Mean difference = 40.1 ms)

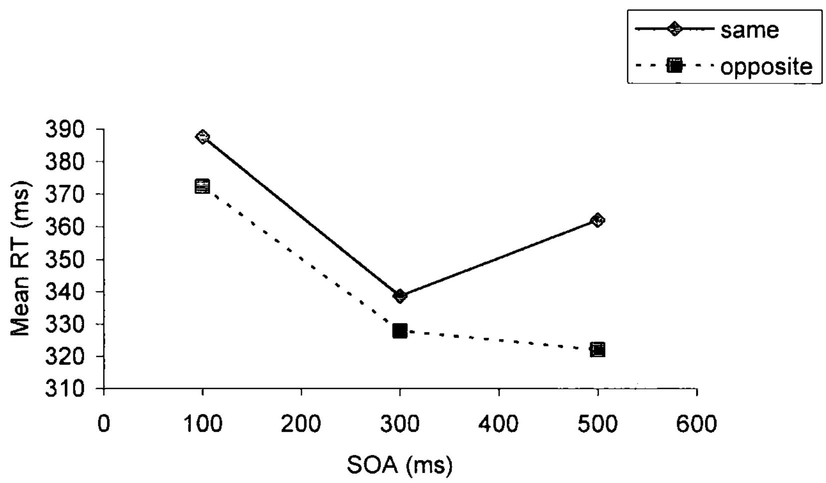


Figure 3.4 Mean RT to Same and Opposite Cued Targets at 3 SOAs

3.5.4 Discussion

The results of Experiment 10 again show a clear and unsurprising effect of SOA. Just as in all previous experiments, with increasing cue/target onset time, the response times decreased.

There was also an effect of the Cue side where reaction time to targets on the Same side as the cue were significantly slower than times to targets on the Opposite side. This disparity mainly being the result of a large difference at 500 ms SOA. (The mean Same-Opposite RT difference at 500 ms was 40.1 ms.)

The interaction between Cue side and SOA was also significant. However, unlike Experiments 7 and 8 there was no apparent facilitation present, only a large measure of inhibition. Although it might be problematic to compare the levels of inhibition obtained in this Experiment with those in Experiment 9 (because of the reported discrimination problems), there is no doubt that the amount of inhibition present is large (comparable to that in Experiment 8). This result seems to confirm the finding in Experiment 8 and appears to contradict the notion of an additive dual component IOR. (But see also Discussion to Experiment 8 for other possible explanations of result.)

Finally, there was also no evidence of generally enhanced processing. Comparing the RTs of Experiment 10 to those of Experiments 7, 8, and 9 produced the following ordering of overall mean RTs: Experiment 9 > Experiment 10 > Experiment 7 ≥ Experiment 8. (The only significant differences were between Experiment 9 and Experiments 7, 8 and 10. None of the other comparisons reached significance.) So, just as in Experiment 9, neither did this study appear to produce a narrowing of attention, nor did it result in enhanced processing of this reduced size cue area.

3.6 General Discussion

The four experiments presented in this chapter manipulated the size of attentional focus and presence of a peripheral cue marker in an attempt to reproduce previous exogenous cueing findings and investigate further the nature of components of visual orienting, and in particular that of inhibition of return (IOR).

All four experiments presented in this chapter showed clear effects of an SOA manipulation (see Table 3.5 for overall summary of findings). Although the cue was spatially uninformative about the location of the subsequent target (cue/target probabilities in all four experiments were set at 50% Same side and 50% Opposite side when a target appeared), it did give the participants some temporal information so that as the SOA increased response times to targets generally decreased.

Table 3.5 Summary of results for the 4 exogenous cueing experiments (i.e. Experiments 7-10)

	SOA	Cue side (Same/Opp)	Interaction: Cue side x SOA
Expt 7	sig	ns	sig
Expt 8	sig	sig (Same>Opp)	sig
Expt 9	sig	ns	ns
Expt 10	sig	sig (Same>Opp)	sig

Experiment 7 replicated previous exogenous cueing studies: both facilitation of RTs for Same side targets over Opposite side targets and inhibition was found and this despite the absence of a 'neutral' or central cueing condition, or a reorienting fixation flash.

Experiments 8 and 10 looked at the effects of removing the cue-marker (or placeholder). It had been postulated that, according to Tipper's dual component view of IOR, this should elicit a reduction in the amount of inhibition produced. Both Experiments 8 and 10, in comparison to Experiment 7 (and Experiment 9, though perhaps this is not a suitable contrast) showed increased amounts of IOR which seems on the surface to reject a dual, and indeed also McAuliffe, Pratt, and O'Donnell's single-component, view. However, the specific methodological set-up used in these (Experiments 7-10) studies may not have provided enough evidence to reject either view.

The difference in cue-target onset times investigated was relatively small. SOAs of only 100, 300, and 500 were used since it was initially thought that these would provide a suitable range to look at facilitation and inhibition in exogenous cueing. Perhaps increasing the range of SOAs used would provide further evidence to support or negate the dual and single views. However the patterning of results found in Experiments 8 and 10 shows no indication of a downward trend of IOR.

The cue-marker absent technique was constructed to generate only a location-based IOR. Other workers using static displays have used similar, but not identical methods. Perhaps, this particular form of exogenous cueing did not solely create a location-based IOR, but also an object-based IOR (for example, by generating a new, albeit fleeting, box on the screen) which together produced a larger amount of inhibition than the comparable location- plus object-based IOR (e.g. in Experiment 7). The present experiments unfortunately do not allow for any clear conclusions on this issue.

A possible follow-up to try to confirm the confound relating to these object-based effects would be to remove the target from the experiments and ask participants to simply respond to the onset of the cue. If the cue markers are not equally salient, that is, if there is a RT difference between cue markers presented on an existing object (i.e. as in Experiments 7 and 9) and those presented 'alone' (i.e. as in Experiments 8 and 10), then one could assume a confound existed and the differing forms of exogenous cues created different forms of IOR during the Experiments described in this chapter.

The aim of Experiment 9 was to investigate whether decreasing the size of attentional focus would change the nature of responding produced as well as provide a comparison level of IOR for Experiment 10. The results were a little unexpected since only effects of the cue-target onset time were found. Participants complained that the task was not one of simple target detection, but more like a discrimination task because of the small size of the target cross and cue-marker box. The experiments should have been designed such that targets in all of the experiments were equally and easily discernible from the other stimuli in the visual display. Studies have shown that discrimination tasks, or detection tasks that are modulated due to task demands (such as this one), may only show IOR at longer SOAs, so it is possible that this may account for the failure to find such attentional effects.

Finally, the design of Experiments 7-10 was intended to enable distinctions between object- and location-based inhibition of return and in particular to look at levels of IOR in static displays in the absence of location markers. However, the presence or removal of cue-marker boxes also brought about profound differences in the levels of contrast. For example, as just mentioned, the cue-marker present stimulus display in Experiment 9 created discrimination problems such that the task was no longer one of simple target detection. Jordan and Tipper (1998) overcame this difficulty by creating an ingenious display using the Kanizsa illusion. The presence or absence of objects within a field was constructed so that low-level metacontrast was matched. The experiments described in this chapter clearly do not control for such contrast effects making interpretation of comparisons problematic.

In conclusion, the results of these experiments have reproduced some aspects of earlier studies of exogenous cueing. Both facilitatory and inhibitory components were found and measured, but explanations of static display findings in the absence of cue-markers (placeholders) and IOR were not resolved. The next chapter turns to address issues relating to attention to objects which although using an endogenous symbolic cueing technique, also draws on exogenous methodology.

Chapter 4

Endogenous cueing with detection tasks and the nature of attentional representation.

4.1 General Introduction

This chapter describes four endogenous central symbolic cueing experiments in an attempt to use a detection task to demonstrate object-based attentional representation.

A number of experiments have demonstrated that attention can be allocated to locations in space or to perceptual objects. Generally, studies employing endogenous cueing techniques have supported a space- or location- based form of attentional representation, whereas exogenous cueing techniques have demonstrated the possibility of attention being directed to objects. Furthermore, very few of the latter studies with static displays have employed methodologies other than those using divided visual attention tasks. Experiment 11 attempts to address this issue by presenting participants with an endogenous cueing detection task investigating the effects of four different 'object' box-frame displays on response times to targets occurring within the central six degrees of the visual field. In this experiment, there is a central fixation point and two possible target locations 2^0 to the left and right of fixation, indicated by the presence of two small target position markers. As usual in many endogenous cueing tasks, following a variable interval the fixation point is replaced by a symbolic cue which is either a Neutral plus sign, or a Valid or Invalid arrow cue. The objects are box frames which always include the fixation. On a quarter of the trials, the box frame contains the target position (TP), but not the non-target, or other, position (OP) (trial type labelled: TP:In, OP:Out) on another quarter of trials the box frame contains the non-target position, but not the target position (trial type labelled: TP:Out, OP:In); on a further quarter of the trials, the frame contains both target and non-target positions (trial type labelled: Bothin); and in the remainder of trials, the frame contains neither position (trial type labelled: Bothout). The aim is to ascertain whether visual stimuli 1^0 away from the position to be attended in the shape of a box frame, and provided before the target, modifies visual attention effects, indicating some form of object-based, or perceptual-grouping of attentional, representation. If these box frames form some perceptual unit, or object representation, then it might be expected that the Bothin (and perhaps a TP:In, OP:Out) type frames would result in faster response times, or some other form of differential attentional effects, than Bothout (and perhaps TP:Out, OP:In) trials.

If an effect of being inside or outside of the box frame is found in Experiment 11, it could be argued that the results were not as a direct consequence of creating an object representation, but as a consequence of the visual stimuli surrounding the target: when a target is 'in', it has different visual stimuli surrounding it than when it is 'out'. In order to attempt to rule out such explanations, in Experiment 12 the upper and lower horizontal components of the box frame were removed so that the targets were no longer perceptually inside or outside of a frame, but nevertheless some properties of the stimuli surrounding the target were retained. If an effect of this 'line frame' is present, then the results in Experiment 11 cannot be accounted for by a simple encircling of the space to be attended, but rather that some boundary crossing effect may be the cause.

A number of studies, including the experiments of the previous chapter, have found different attentional effects as a consequence of the presence or absence of landmarks or placeholders. Experiment 13 investigated the use of position markers in the box frame methodology. The same stimuli and procedure were used here as in Experiment 11 except that the two small target position markers no longer appeared with the cue and box frames. It is supposed that the absence of these position markers may change the way in which participants direct their attention or the way in which they generate a representation of the space on which attention is directed.

Experiment 14 was a partial replication of Experiment 11 except that the box frames were moved into the periphery. Pairs of identical boxes appeared 10^0 to the left and to the right of fixation. Participants were again asked to make a response as quickly as possible, following a central cue (Neutral, Valid, or Invalid), to a target appearing in one of four possible locations: 8 and 12 degrees to the left or right of the central fixation point. These target positions were framed by either a Bothin or a Bothout type of box. (The other two conditions TP:In, OP:Out and TP:Out, OP:In were omitted from the design.) It was predicted that if the visual stimuli are grouped together and that being inside a box frame is beneficial, then Bothin responding would be faster than Bothout reaction times. It was also predicted that if a simple spatial gradient of attentional distribution is in operation then greater Costs and Benefits would accrue to Near targets than to Far targets.

4.2 Experiment 11

Endogenous cueing with targets and box frames in a central location using a detection task

4.2.1 Introduction

Recently studies of covert attention have been concerned with whether visual selection of stimuli is based on spatial location, that is attention is directed to unsegmented, unparsed regions of the visual field, or is based on objects, that is attention is directed to some forms of segmented, parsed, Gestalt, perceptual groups that may form an invariant object structure or coherent whole. (The literature is extensive, the following represent just a few of the relevant studies spanning more than 20 years: Duncan, 1984; Egly, Driver & Rafal, 1994; Eriksen & Eriksen, 1974; Kramer & Jacobson, 1991; Law & Abrams, 2002; Posner, 1980; Posner, Snyder & Davidson, 1980; Vecera & Farah, 1994) There is now a growing consensus that both forms of attentional representation, space-based and object-based, may coexist, but the nature of this coexistence is still unclear. This has led researchers to alter their general approach to a search for the conditions under which these forms operate and interact.

One of the possible mediators distinguishing between space- and object-based attention is that of the mode of attentional cueing or control. It is generally accepted that there are two forms of this mode: exogenous and endogenous. Exogenous cueing, typically a spatially uninformative peripheral luminance change near to the target location, is described as involuntary, unconscious, automatic, stimulus-driven, fast and has more often been found to invoke object-based attention Endogenous cueing, typically a spatially informative centrally presented symbolic cue, can be described as voluntary, conscious, goal-directed, has a slower time course, and usually found to induce space-based attention. (E.g. Jonides, 1981, Nakayama & Mackeben, 1989; Macquistan, 1997; Müller & Rabbitt, 1989). If it is indeed the case that exogenous cues only elicit object-based attention and endogenous elicit space-based attention, then this would have important ramifications not only for the understanding of these forms of cueing and attentional representation, but also for any proposed theoretical modelling. For example, Müller & Rabbitt (1989) conclude that there are two separate attentional mechanisms responding to the two modes of control, that overall performance is a result of the interaction of the two mechanisms, but that each mechanism serves the same limited-capacity attentional system. If, as Abrams and Law (2000) comment, "one type of orienting...can lead to object-based radiation of attention but another type of orienting...cannot, the notion of a common attentional system may require reassessment." (p819)

Typically, the evidence for object-based attention comes either from divided visual attention studies where the location or features of stimuli are investigated in relation to their object structure or spatial grouping (e.g. Duncan, 1984; Egly, Driver & Rafal, 1994; Rock & Guttman, 1981; Yantis & Moore, 1995, Yantis & Vaughan, 1998), or from studies were attention is directed to moving objects (e.g. Driver & Baylis, 1989; Kahneman, Treisman, & Gibbs, 1992; Tipper, Driver, & Weaver, 1991; Tipper, Weaver, Jerreat, & Burak, 1994, Yantis, 1992). Nearly all of the reported studies showing object-based attention have used exogenous cueing of one form or another. Only a few researchers have attempted to demonstrate object-based representations specifically using endogenous cueing and the majority of these have met with failure. For example, Macquistan (1997) altered the double rectangle cueing paradigm of Egly, Driver and Rafal (1994) to compare the two types of cueing. Using a spatially non predictive peripheral exogenous cue he found a significant object-based effect. However, using a centrally presented spatially predictive symbolic cue-arrow (i.e. valid trials were set at 75% cue-target predictability) he found no such object-based effect. (See also Arrington, Dagenbach, McCartan, & Carr, 2000; Dagenbach, Goolsby, Neely, & Dudziak, 1997; Neely & Dagenbach, 1996; all cited in Goldsmith & Yeari, 2003). There have been some limited successes. Notably, Abrams and Law (2000), Law and Abrams (2002), and Goldsmith and Yeari (2003) who criticized previous attempts due to their lack of extended cue-target interval (e.g. Macquistan (1977) used only one cue-target interval) and their confounds with initial focus of attention. Both sets of workers successfully showed object-based effects and will be returned to in later discussions.

Experiment 11 attempted to investigate the possibility of object-based representations with endogenous cueing using a simple detection methodology. As usual in many endogenous cueing experiments, the cue was either a spatially (relatively) uninformative Neutral plus sign, or a Valid or Invalid arrow cue. In this experiment there were two possible target positions: In all conditions these were 2 degrees to the left and right of a central fixation point. A box frame, which always contained the fixation point, appeared with the onset of a cue which replaced fixation. The size and location of the box frame varied: On a quarter of the trials, the box frame contained the target position (TP), but not the non-target, or other, position (OP) (trial type: TP:In, OP:Out) on another quarter of trials the box frame contained the non-target position, but not the target position (trial type: TP:Out, OP:In); on a further quarter of the trials, the frame contained both target and non-target positions (trial type: Bothin); and in the remainder of trials, the frame contained neither position (trial type: Bothout).

If visual attention operates on perceptual groupings and the box frames in this experiment define such a perceptual grouping (or object), one should expect a pattern of results which varies according to the nature of the frame. If, however, being inside or outside of the frame is without effect on the mental representation on which attention operates and participants can orient towards the cued position without any interference produced by the frame, then one might expect no detection time differences.

Additionally, do attentional effects also depend on what happens to the 'other' non-target position? Previous experiments (e.g. Egly, Driver & Rafal, 1994) have mainly focussed on targets and non-target locations all within an encompassed space. In this experiment the location of the non-target position was also manipulated. However, as a consequence of this, there was an additional change in the box frame size. Bothin frames being larger (6^0x6^0) than TP:In, OP:Out and TP:Out, OP:In frames (4^0x6^0) which were larger than Bothout frames (2^0x6^0). The results of Experiments 8 and 10, which also subtended the central 6^0 of the visual field, where the size of box was manipulated showed no significant overall RT differences indicating that the size of the box frame should not be a factor. However, there were differences between Experiments 7 and 9 which also manipulated box size, so any discussions of significant box frame results perhaps should take frame size into consideration.

As mentioned earlier, Goldsmith and Yeari (2003) criticized earlier attempts to find object-based attention using endogenous cueing for their lack of an extended SOA range. Experiment 11, therefore, used three cue-target intervals (100, 500 and 1000 ms). It was predicted that these should be sufficient to capture the effects of the exogenous cueing component of the design (i.e. the initial onset of the box frame, though it was expected that this should remain consistent across trial types) and the endogenous cueing (symbolic cueing), where the time-course of effects is more protracted, in addition to being able to produce a clearer analysis of the different costs and benefits.

Finally, it was decided to present the box frames in a random sequence, rather than in a blocked procedure (i.e. all trials were intermingled, rather than all Bothin trials presented in a block together, all Bothout trials presented together, etc.), as it was thought that this randomisation would be more 'ecologically valid' (our visual world consists of variety), and would cause participants to take more notice of the frames.

4.2.2 Method

Participants

Eight participants (five females and three males), aged between 20 and 53 participated in one practice session lasting approximately 5 minutes, and two experimental sessions each lasting 20 minutes. (Two participants had not previously taken part in a reaction time experiment, the remaining 6 had participated in at least one such study.)

The participants were undergraduates, postgraduates, and staff at the University of Durham. All were volunteers and were paid at a rate of £5.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

The experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh Performa 630, with stimuli presented on an Apple MultipleScan 1705 Display screen.

The keyboard space bar was used as the response. The participant placed their chin on a rest fixed to produce a 57cm viewing distance from the screen. The room was dimly illuminated by one of the room-lights.

Stimuli

The stimuli used in this symbolic cueing experiment consisted of the following four types of box frame which manipulated whether the target position (TP) and the non-target, or other position (OP), were inside or outside of a box frame (See Figure 4.1 for examples of the box frame stimuli):

- **Bothin** - both the Target Position (TP) and the Other Position (OP) were inside a box which was a 6^0 unfilled square;

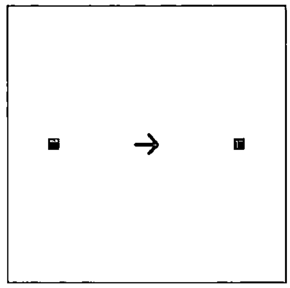
TP:In, OP:Out - the Target Position was inside the box and the Other Position was outside the box which was a 4^0 x 6^0 unfilled rectangle ;

- **TP:Out, OP:In** - the Target Position was outside the box and the Other Position was inside the box which was a 4^0 x 6^0 unfilled rectangle ;

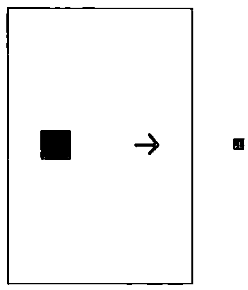
- **Bothout** - both the Target Position and the Other Position were outside the box which was a 2^0 x 6^0 unfilled rectangle

Other stimuli are described in the Procedure section below.

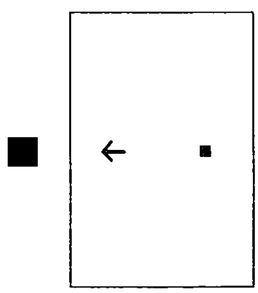
Bothin box frame showing the display before a target appears (or on a catch trial) including the two position markers and an arrow cue



TP:In, OP:Out box frame showing an Invalid trial with a left target



TP:Out, OP:In box frame showing a Valid trial with a left target



Bothout box frame showing a Neutral cue and position markers before a target appears

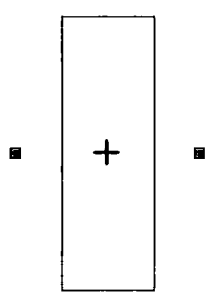


Figure 4.1 The four box frame types illustrating the position markers, targets, and Valid, Invalid, and Neutral cue types.

Design

The design was a within-subjects design with 3 independent variables: Box Frame (4 levels: Bothin, TP:In, OP:Out, TP:Out, OP:In, Bothout); Cue Validity (3 levels: Invalid, Neutral, and Valid); and SOA (3 levels: 100, 500, 1000 ms). The dependent variable was the mean response time to detect a target.

Procedure

At the start of the experimental session, the participant was seated in front of the screen and asked to place their chin on the chin rest and keep their eyes positioned on the central location throughout the experiment. The participants pressed the space bar to initiate the block of trials.

Each trial began with a central fixation stimulus (a 0.5^0 diameter circle with a 0.1^0 central dot) appearing on the screen. After an interval varying between 400 and 1000 ms, the fixation was replaced by a cue, a single box frame and 2 position markers.

The position markers (0.2^0 filled black squares – see Figure 4.1) indicated the possible locations of the target which could occur at 2^0 to the left or right of fixation.

The cue, which replaced the fixation point, could be one of three types: a Valid (V) cue, an Invalid (I) cue, or a Neutral (N) cue.

The Valid and Invalid cues consisted of an arrow (0.5^0 in length - see Figure 4.1) pointing to the left or to the right. On these arrow cue trials, there was a probability of 0.8 that, if a target appeared, it would appear in the location indicated by the arrow. (And a probability of 0.2 that, if a target appeared, it would appear in the other location; that is, the one not indicated by the arrow cue.) In other words, on any arrow cue trial the participant could expect the target to appear in the indicated location about 80% of the time. Hence, the participants were asked to try to focus their attention, but not their eyes, on the position indicated by the arrow.

The Neutral cue was a cross (0.5^0 in length and height - see Figure 4.1) which gave no information about the likely location of the target; in other words, there was a probability of 0.5 that, if a target appeared, it would appear to the left or to the right of the fixation location. On these trials, participants were instructed to try to spread their attention evenly across the screen.

As previously mentioned, in addition to the position markers, and cue replacing the fixation point, a box frame appeared on the screen. There were 4 types of box frame described in terms of the target location and the other position. (See section on Stimuli above for description and Figure 4.1 for examples of the box frames.)

N.B. The fixation point was always in the centre of the screen - not the centre of a box - and the position markers and targets locations at 2^0 to the right and to the left of the screen centre/fixation point. Hence the Bothin and Bothout types of box were centred on the screen whereas the TP:In, OP:Out and TP:Out, OP:In boxes were not.

The cue, position markers, and box appeared for one of three durations: 100, 500, or 1000 ms. That is there were three SOA (Stimulus Onset Asynchrony) durations used throughout these experiments.

Following the appearance of the box frames, cue, and the position markers, a target (a 0.6^0 filled black square – Figure 4.1) appeared either to the right, or to the left of fixation, replacing one of the position markers.

The participant's task was one of a simple reaction time, a single key press with their preferred hand, to the onset of this visual target.

No formal breaks during the 2 experimental sessions were imposed on the participants. Instead participants were encouraged to take as many rests as they required. They were instructed simply not to respond whenever they needed a break and to allow at least 5 seconds to elapse before restarting the experiment by pressing the response key. These trials were discounted from the analysis.

After the participant had pressed the response key, the next trial began with the reappearance of the fixation point.

Occasionally (approximately 9% of the time) a catch trial occurred. Here, the fixation point was replaced by the cue, box, and position markers, but no target appeared. After a varying interval (100, 500, or 1000 ms) the cue, box, and position markers would be replaced by the fixation point and the next trial began.

Before the experimental sessions the participants were given comprehensive instructions about the experiment and then completed a practice block. Only when the experimenter was certain that the participants understood the procedure did the experiment proper begin. Following the experimental sessions the participants were debriefed.

The stimuli were presented in two experimental blocks, where each block contained 48 Valid trials, 60 Neutral trials, 12 Invalid trials and 12 catch trials for each of the four box frames (i.e. 528 trials per block). These were randomised before presentation.

4.2.3 Results

Reaction Times (RTs) faster than 100 ms were discarded as anticipations and RTs greater than 1500 ms were also eliminated from the analysis since they were regarded as a lapse in the participant's attention, or indicated that they had taken a rest.

The mean reaction times (RTs) were calculated for each of the 8 participants in the experiment under the four Box Frame conditions, for Invalid (I), Neutral (N), and Valid (V) trials at each of the 3 SOAs (i.e. 100, 500, 1000 ms).

A three factor ANOVA was performed to examine the data. There were four levels of the first factor: Box Frame (Bothin, TP:In, OP:Out, TP:Out, OP:In, Bothout); 3 levels of the second factor: Cue Validity (Invalid, Neutral, and Valid); and three levels of the third factor: SOA (100, 500, 1000 ms).

The results are shown in Table 4.1 and Figure 4.2. As can be seen, the results show a clear effect of the Cue Validity manipulation. The ANOVA produced a significant Cue Validity main effect ($F(2,14) = 102.4$, $p<0.0001$). Valid trials produced fastest responding (mean RT = 335 ms), Neutral trials an intermediate level of responding (mean RT = 354 ms), and Invalid trials slowest reaction times (mean RT = 376 ms). Pairwise comparisons showed significant differences between each level of Cue Validity (all to at least $p<0.001$).

In endogenous cueing tasks the RTs of Valid and Invalid trials are often compared with RTs to the Neutral trials. These comparisons are called Benefits (i.e. Neutral RT minus Valid RT) and Costs (i.e. Invalid RT minus Neutral RT) respectively.

Table 4.1 Experiment 11: Table of RT means and associated Costs and Benefits for each Box Frame type, Validity, and SOA

	Box Frame											
	Bothin			TP:In, OP:Out			TP:Out, OP:In			Bothout		
Validity / SOA	I	N	V	I	N	V	I	N	V	I	N	V
100	397	382	381	393	388	365	397	387	375	399	402	381
500	401	341	314	365	340	318	376	344	329	382	336	317
1000	353	323	308	359	337	308	355	333	312	337	333	315
Mean	384	349	334	372	355	331	376	355	339	373	357	338

Corresponding Costs (C) and Benefits (B)

		Box Frame				
		Bothin	TP:In, OP:Out	TP:Out, OP:In	Bothout	Mean
100	B	1	23	12	21	
	C	15	5	10	-3	
500	B	27	22	15	19	
	C	60	25	32	46	
1000	B	15	29	21	18	
	C	30	22	22	4	
Overall	B	15	24	16	19	**18.6**
	C	35	17	21	16	**22.3**

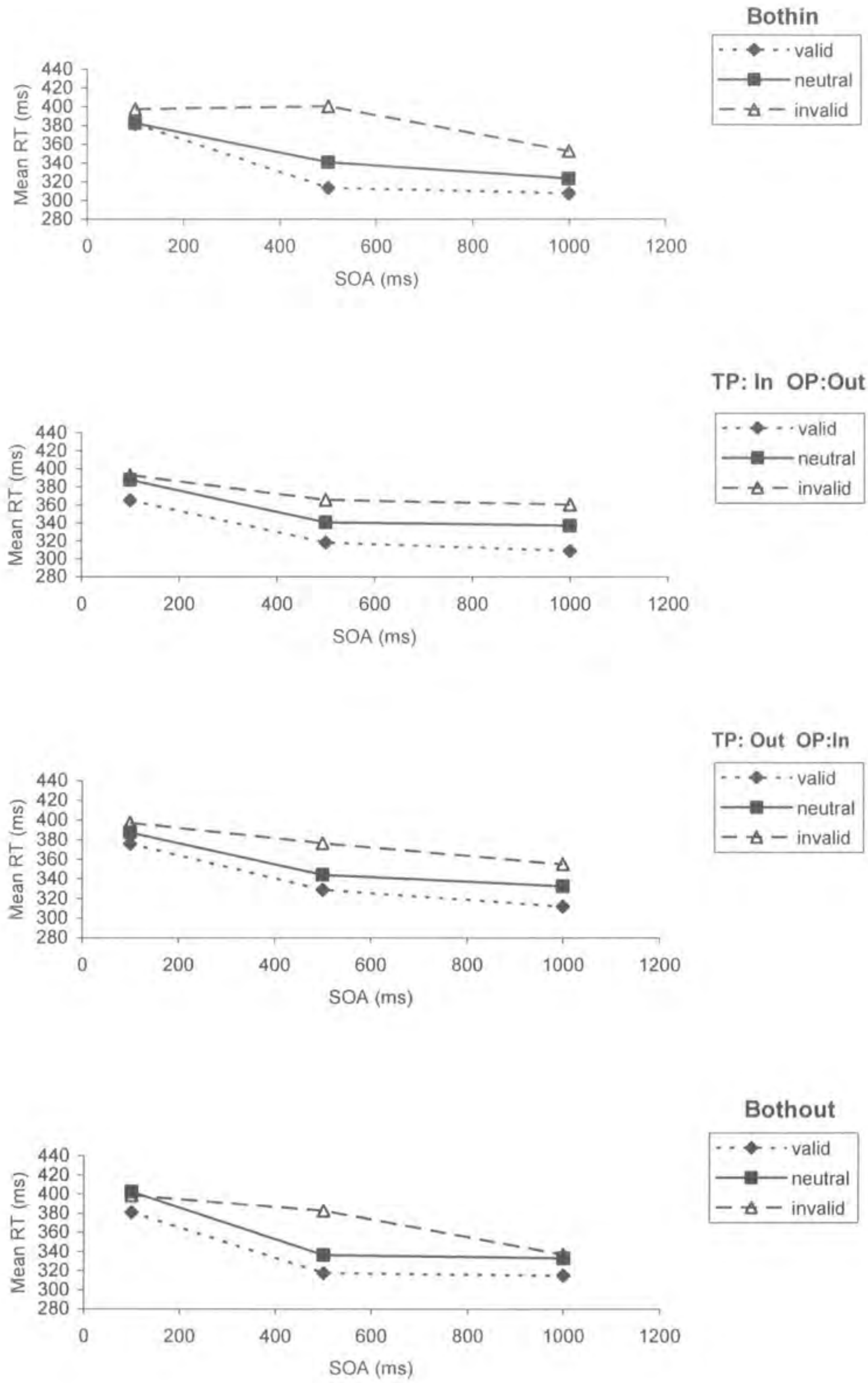


Figure 4.2 Experiment 11: Mean RTs for the four Box Frames at each SOA and Validity

The overall Benefits were similar across the four Box Frame conditions, with TP:In, OP:Out being just slightly higher than the other three conditions. The overall mean Benefits were 18.6 ms. (Also see Table 4.1 for further breakdown of Benefits.)

The overall Costs varied across the four Box Frame conditions, with Bothin having the highest, then TP:Out, OP:In, and then TP:In, OP:Out and Bothout having the smallest Costs. The overall mean Costs here were 22.3 ms. (Also see Table 4.1 for further breakdown of Costs.)

A significant main effect of SOA was found ($F(2,14) = 52.304$, $p<0.0001$). As the SOA increases so the RT decreases. The optimum SOA in this experiment was 1000 ms, which produced a mean RT of 331 ms, as opposed to a mean of 347 ms at an SOA of 500, and 387 ms at an SOA of 100. Pairwise comparisons showed significant differences between each level of SOA (all to at least $p<0.01$).

SOA was also found to interact with the validity of the target ($F(4,28) = 8.764$, $p=0.0001$).

There was no significant main effect of Box Frame ($F(3,21)=0.378$, $p=0.7701$). Nor were the remaining 2-way and 3-way interactions significant: Box Frame x Cue Validity ($F(6,42) = 1.382$, $p = 0.2443$); Box Frame x SOA ($F(6,42) = 1.428$, $p = 0.2268$); and Box Frame x Cue Validity x SOA ($F(12,84) = 1.377$, $p = 0.1933$).

4.2.4 Discussion

Due to the nature of the results from Experiments 11 and 12, discussion of the findings will be dealt with together in a single Discussion section following Experiment 12.

4.3 Experiment 12

Endogenous cueing with targets and line frames in a central location using a detection task

4.3.1 Introduction

Experiment 12 was constructed as a 'control' comparison for Experiment 11 (and for later experiments). If an effect of the box frame, and being inside or outside of a box, is found, then one possible criticism of the experiment is that the results were not a direct consequence of participants generating an object representation. It is possible that the same results could be as a consequence of the visual display appearing with the to-be-attended locations. For example, when a target is 'in', it has different visual stimuli surrounding it than when it is 'out'. In an attempt to partially rule out such criticisms, the upper and lower horizontal elements of the box frame were removed so that the target and non-target positions were no longer perceptually inside or outside of a frame, but, at least to some extent, the visual properties of the display around these positions were retained. If an effect of this 'line frame' is present, then results using box frames cannot be accounted for by an encircling, or boxing, of space, but rather that some boundary crossing or distractor effect may be the cause. It is possible that participants could view the line frames as a cross-section through a pipe thereby creating an object, but when a pilot sample was asked to describe the stimuli, none saw them as representing an object, but simply as lines and small squares. Descriptions of the stimuli of Experiment 11, however, clearly indicated that participants viewed the box frames as objects containing, or not containing other squares.

4.3.2 Method

Participants

Eight participants (five females and three males), aged between 21 and 41 years participated in one practice session lasting approximately 5 minutes, and two experimental sessions each lasting 20 minutes.

Four participants had not previously participated in any similar reaction time experiments, the remaining four had been involved in at least one such study. 7 of the participants were different from those used in Experiment 11, one was the same.

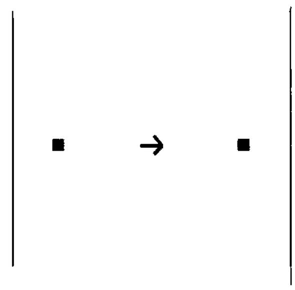
The participants were undergraduates, postgraduates, and staff at the University of Durham. All were volunteers and were paid at a rate of £5.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment

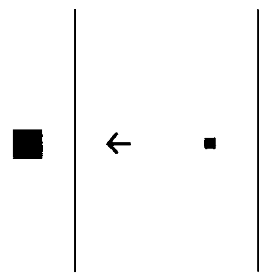
Apparatus, Design and Procedure

The apparatus, design and procedure were identical to the previous experiment, except that the stimuli used were slightly different. The horizontal part of all the box frames was removed to leave 2 vertical lines making up each line frame. (See Figure 4.3)

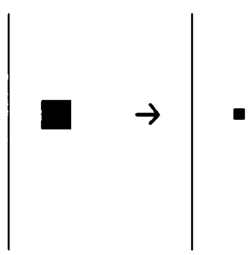
Bothin line frame showing the display before a target appears (or on a catch trial) including the two position markers and an arrow cue



TP:In, OP:Out line frame showing a Valid trial with a left target



TP:Out, OP:In line frame showing an Invalid trial with a left target



Bothout line frame with Neutral cue and position markers before a target appears

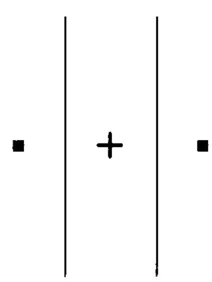


Figure 4.3 The four line frame types used in Experiment 12 illustrating the position markers, targets, and Valid, Invalid, and Neutral cue types.

4.3.3 Results

As in the previous experiment, the mean reaction times (RTs) were calculated for each of the 8 participants in the experiment under the four Line Frame conditions, for Invalid (I), Neutral (N), and Valid (V) trials at each of the 3 SOAs (i.e. 100, 500, 1000 ms). RTs less than 100 ms and greater than 1500 ms were discarded from the analysis.

A three (4x3x3) factor ANOVA identical to the previous experiment was performed to examine the results.

As can be seen from Table 4.2 and Figure 4.4, these results also show a clear effect of the Cue Validity manipulation. The ANOVA produced a significant Cue Validity main effect ($F(1.176,8.230) = 15.335$, $p=0.0003$). Valid trials produced fastest responding (mean RT = 328 ms), Neutral trials an intermediate level of responding (mean RT = 340 ms), and Invalid trials slowest reaction times (mean RT = 361 ms). Pairwise comparisons revealed significant differences between Valid and Invalid trials ($p=0.014$), between Neutral and Invalid trials ($p=0.015$); but a non significant difference between Valid and Neutral trials ($p=0.056$)

The overall Benefits were very similar across the four Line Frame conditions, The overall mean Benefits were 12.5 ms. The overall Costs varied across the four Line Frame conditions, with TP:In, OP:Out having the highest, and then Bothin, TP:Out, OP:In, and Bothout having similar smaller Costs. The overall mean Costs here were 20.3 ms. In comparison to Experiment 11 (Benefits of 18.6 ms and Costs of 22.3 ms), there was a reduction of Benefits, and a very slight reduction in Costs. (See Table 4.2 for breakdown of Costs and Benefits.)

Table 4.2 Experiment 12: Table of RT means and associated Costs and Benefits for each Line Frame type, Validity, and SOA

Line Frame

	Bothin			TP:In, OP:Out			TP:Out, OP:In			Bothout		
Validity	I	N	V	I	N	V	I	N	V	I	N	V
SOA												
100	386	369	372	420	383	365	379	391	392	378	386	375
500	338	327	303	344	313	302	352	325	305	349	328	318
1000	339	315	301	342	308	300	344	314	295	356	325	307
Mean	354	337	325	369	335	322	358	343	331	361	346	333

Corresponding Costs (C) and Benefits (B)

Line Frame

		Bothin	TP:In, OP:Out	TP:Out, OP:In	Bothout	Mean
100	B	-3	18	-1	11	
	C	17	37	-12	-8	
500	B	24	11	20	10	
	C	11	31	27	21	
1000	B	14	8	19	18	
	C	24	34	30	31	
Overall	B	12	13	12	13	**12.5**
	C	17	34	15	15	**20.3**

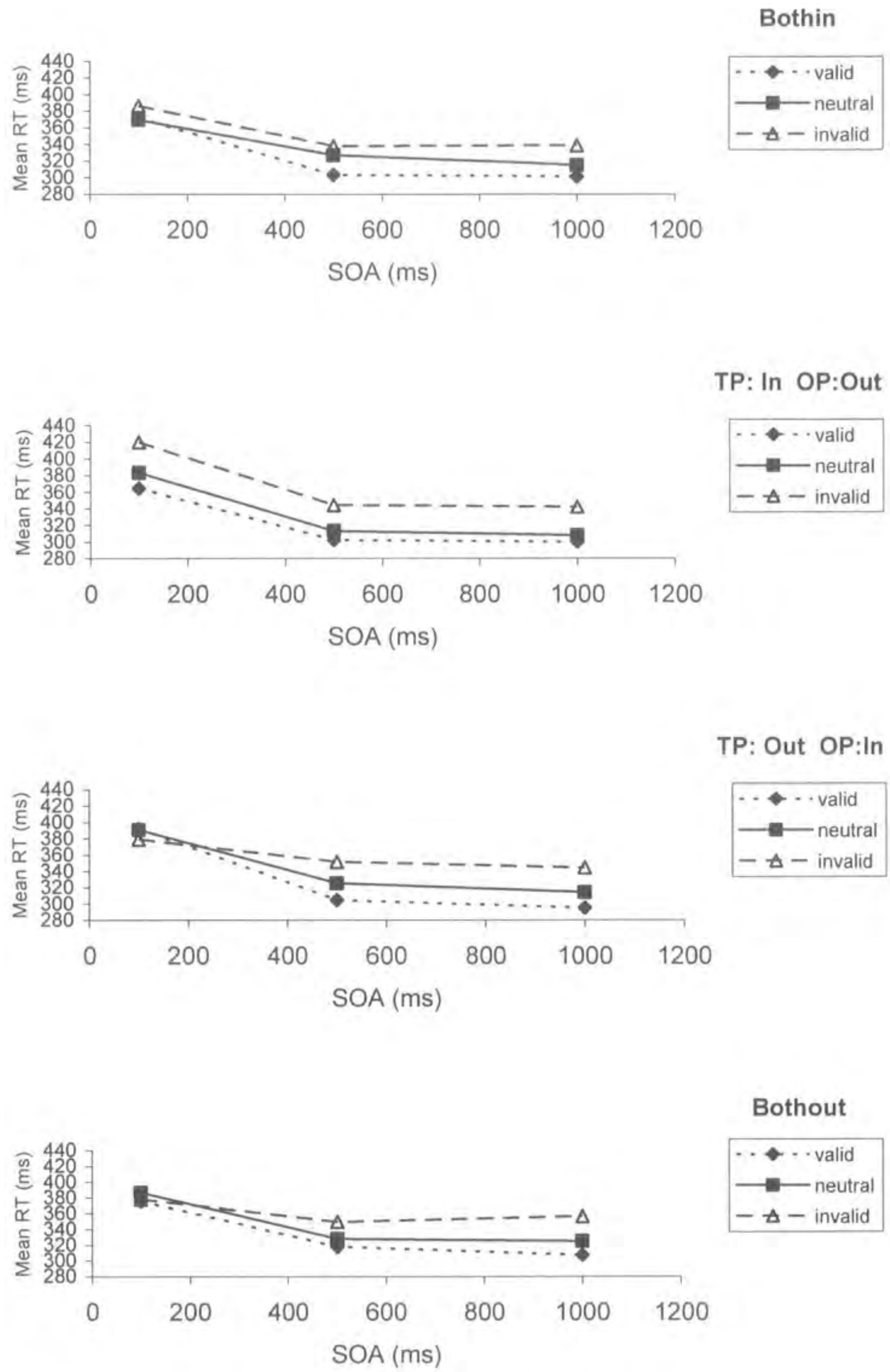


Figure 4.4 Experiment 12: Mean RTs for the four Line Frames at each SOA and Validity

In this experiment, as in Experiment 11, a significant main effect of SOA was found ($F(1.053,7.371) = 20.390$, $p=0.002$). The optimum SOA in this experiment was again 1000 ms, which produced a mean RT of 320 ms, as opposed to a mean of 325 ms at an SOA of 500, and 383 ms at an SOA of 100. Pairwise comparisons revealed significant differences between RTs at SOAs of 100 ms and 500 ms ($p=0.013$), between RTs at SOAs of 100 ms and 1000 ms ($p=0.005$); but a non significant difference RTs at SOAs of 500 ms and 1000 ms ($p=0.389$).

The interaction between Cue validity and SOA was also significant ($F(4,28) = 2.996$, $p=0.0355$).

There was no significant main effect of Line Frame ($F(1.426,9.979) = 2.393$, $p = 0.149$). Nor were the remaining 2-way and 3-way interactions significant: Line Frame x Cue Validity ($F(6,42) = 1.555$, $p = 0.1843$); Line Frame x SOA ($F(3.43,224.01) = 1.696$, $p = 0.19$); and Line Frame x Cue Validity x SOA ($F(4.004,28.025) = 1.739$, $p = 0.169$).

4.3.4 Discussion

Due to the nature of the results from Experiments 11 and 12, discussion of the findings will be dealt with together in this Discussion section.

Both Experiments 11 and 12 produced a significant main effect of SOA. As the time between the cue and target increases, so the RT decreases. This result has been well documented in the literature (e.g. Posner & Boies, 1971; Brebner & Welford, 1980; Niemi & Naatanen, 1981). The cue (and indeed the frame and position markers) has a general alerting effect – they act as a temporal warning signal - which prepares the participant for the onset of the target.

Additionally, in both experiments, SOA was found to interact with the Cue Validity: very short SOA's producing little difference between the Valid, Neutral, and Invalid trials; greater RT differences being found at longer SOAs. This again, is not an unexpected finding, since the time course of endogenous cueing effects is more extended, occurring at longer cue-target onsets than some exogenous effects.

As is usually found in studies with endogenous cueing, the results from both experiments show a clear effect of the Cue Validity. In general, Valid cues produced fastest responding, and Invalid cues slowest responding.

The overall benefits (i.e. Valid-Neutral RT difference) and costs (i.e. Invalid-Neutral RT difference) produced in the two experiments were comparable: in Experiment 11 they were 19 ms and 22 ms respectively and in Experiment 12 they were 12 ms and 20 ms respectively. The experimental situation has obvious differences from the classic Posner task (as described, for instance, in Posner Nissen, & Ogden, 1978) and has indeed produced slightly lower benefits and costs than they found: 25 and 40 ms respectively. It is possible that these Cost / Benefit differences can be accounted for by the spatial location of the targets. In Experiment 11 and 12 targets were only 2 degrees either side of fixation, whereas in Posner, Nissen, & Ogden's experiment they were 14 degrees apart. However, Posner (1978) reported that costs and benefits were very regular. They measured stimuli varying from 0.5 to 25 degrees eccentricity and found little variation. Posner (1978) did, however, report a decrease in cost and benefit differences if the task difficulty or complexity increased, which could account for the reduction in Cost/Benefit differences found in Experiments 11 and 12.

It is interesting to note that such Costs and Benefits are found at all locations so close to the point of gaze. Why should participants need to shift their attention within this small foveal region? It is clear, nevertheless, because of the

Cue Validity findings, that they do. This is supported by other researchers, for example Downing and Pinker (1985) who showed Costs and Benefits to targets across a wide range of eccentricities (i.e. 1.25^0 to 11.25^0 from fixation) and moreover (unlike Posner (op.cit.)) found a gradient of attentional distribution such that, in general, costs were greater the closer in to the fovea.

It is tempting to suggest that the decrease in Benefits from Experiment 11 to Experiment 12 (19 ms and 12 ms respectively) was due to a change in the experimental stimuli used. However, neither experiment produced a significant (main or interaction) effect of the Box / Line Frame. Nor did a combined ANOVA reveal any significant differences between the two experiments ($F(1,14)=0.320$, $p=0.5807$). It appears that being inside or outside of a box frame, or crossing a 'frame line', has no effect. It does not seem to be information that is contained within the mental representation on which attention operates in these two experiments.

What then might account for these findings?

An assumption made in the design of these experiments was that participants would perceive the stimuli presented as a perceptual group or object and that this would influence their attention shifts. Indeed pilot study descriptions prior to the experiments indicated that participants viewed the stimuli in Experiment 11 as grouped entities and objects (e.g. "it's a square with two little black squares inside it"), but did not view the stimuli in Experiment 12 as such (e.g. "there are two lines and two small marks"). Additionally, verbal reports from participants suggested that they were making use of the surrounding frames in Experiment 11, but were not influenced by the 'frame lines' in Experiment 12. Nevertheless, as has been seen before, subjective reports may not reflect behavioural measures. Mack, Tang, Tuma, Kahn, & Rock (1992) have suggested that there is no grouping prior to attention. This would provide one explanation for my results. However, Mack et al's findings were based on subjective reports of (non-) grouping and it is possible that their participants had grouped the stimuli, but had just 'forgotten' that they had done so. Nevertheless, the lack of main effect of Box / Line Frame clearly seems to indicate a lack of stimulus grouping in Experiments 11 and 12.

In the Introduction to Experiment 11 it was noted that the randomisation procedure chosen was more ecologically valid than a blocked presentation and would cause participants to take more notice of the of the box- and line-frames. However, perhaps this notion was ill-conceived. It is possible that the nature of the task demands (react to the onset of a target which always occurred in one of two locations irrespective of trial type) caused the participants to adapt their control settings. It was of no benefit whatsoever to take any notice of the frames or lines in these experiments – they could be viewed as a distraction to the task. So, despite the presence of involuntary exogenous cueing effects of the onset of the box frame or frame lines which may have caused participants to group the visual components of the display, the voluntary central cueing task may have modified attentional orienting such that these were overridden and participants were only affected by the SOA and cue validity and not by the box, or line, frames. Indeed, Vecera and Farah (1994) make just this point: " if subjects do not need to represent objects as objects but merely detect the onset of some target, then there will be no need to encode them in terms of relatively high-level, object-centred visual representations...Instead, detection may be accomplished using relatively low-level array representations." (p153)

Perhaps if a blocked methodology had been employed, then participants would have made use of the box frame information in aiding detection of targets and an 'object-based' form of attentional control may have been observed. (It is also a possibility that object-based attention may occur with endogenous cueing, but the results from Experiments 11 and 12 show that it cannot be obligatory.)

Another possibility, following on from the above comment on blocking procedure, is that there are indeed separate object-based and spatial-based attentional mechanisms influencing visual processing but perhaps the nature of the task demands in these experiments called on only one of these mechanisms, where no grouping occurs. Perhaps an alteration of the response required may alter the focus of attention or change the attentional mechanism used, causing a grouping, or an influence of grouping to occur. (The next chapter addresses this topic.)

Both these last two issues (i.e. not viewing the stimuli as a group and strategic control) are amongst the points that have been raised by Goldsmith and Yeari (2003). In contrast to interpretations that suggest a conflict between space-based and object-based attentional selection (e.g. Atchley & Kramer, 2001; Law & Abrams, 2002) Goldsmith and Yeari (2003) put forward an attentional-focussing hypothesis which could account for the findings of Experiments 11 and 12. They propose that what must be taken into account are "the detailed temporal and spatial dynamics of attentional focussing during the course of an experimental trial...and, in particular, how those dynamics affect the quality of the object representations that exist at the time of attentional orienting." (p913) and it is the quality of the object representation, and whether it is encompassed within the focus of attention, that ultimately determines the use of object-based or space-based selection. Furthermore, they suggest that the resulting representations will probably not be identical for all conditions and participants since these can also be influenced by both top-down (goal-directed, strategic) and bottom-up (stimulus-driven) factors.

Drawing on the comments from Goldsmith and Yeari (2003) and from earlier experiments looking at distance effects in two- and three-dimensions (Downing & Pinker, 1985; Rizzolatti, Riggio, Dascola & Umiltá, 1987; Hughes & Zimba, 1985; Zimba & Hughes, 1987; Hoffman & Mueller, 1994), a further possible explanation for the lack of a frame effect may stem from the use of landmarks and placeholder objects. In previous studies there has been an inconsistency between results which Hoffman & Mueller (1994) suggest are as a consequence of the effects of placeholders. In both Experiments 11 and 12 position markers were used to locate the possible positions of the target, but perhaps these very position markers led to the null effect. Participants may have viewed the frames as objects, but also viewed the markers as separate objects on which attention could operate.

Referring back to the earlier description "it's a square with two little black squares inside it" suggests that this participant, at least did not view the position markers as part of the square (box-frame), but as distinct objects in themselves. Additionally, the position markers may have caused participants to focus their attention solely on the small area of the markers, rather than to focus attention in the box-frame region. The next experiment investigates the possibility that the use of these position markers affects attentional selection.

One final suggestion for the lack of box- and line-frame effects found in Experiments 11 and 12 is that the targets used were only 2 degrees from fixation. One possibility is that within this small attentional focus, it was not necessary to invoke object representations. Experiment 14 looks at whether moving the box frames into the periphery may induce a space-based form of selection. Furthermore, theories of attention that incorporate eye movements may predict that no object effects would be found in such a central area, but that object-based effects may be likely with more peripheral stimuli. If the intention to make an eye movement is what affects attentional orienting and participants had no such intentions within this central area of the visual field, then moving the frames to a peripheral location may invoke the intention to make such eye movements, resulting in a different attentional effect.

4.4 Experiment 13

Endogenous cueing in the absence of target position markers

4.4.1 Introduction

In the Discussion of Experiments 11 and 12, it was noted that according to Goldsmith and Yeari's (2003) attentional focusing hypothesis the quality of the object representations, the spatial dynamics, and whether the object is within the focus of attention all have a role to play in the determination of object- or space-based selection. Experiment 13 attempts to alter the form of attentional selection by making a small, but perhaps significant change to the stimulus display.

In investigating the effects of distance between expected and actual target location in 2-D separation, a number of researchers apparently produced contradictory results. For example, Downing and Pinker (1985) found that generally RT increased with distance between the expected and real target position, and Rizzolatti, Riggio, Dascola, and Umiltá (1987) reported similar findings within a quadrant and increased costs when the cue and target were on opposite sides of the horizontal or vertical midline. However, Hughes and Zimba (1985, 1987) did not report such effects. They concluded that RTs were uniformly fast when cue and target locations were in the same hemifield and uniformly slow when in different hemifields. Similarly, results from studies of 3-D space have produced inconsistencies. For example, Gawryszewski, Riggio, Rizzolatti and Umiltá (1987) found costs and benefits when cues and targets were located in different depth planes. Ghirardelli and Folk (1996) and Iavecchia and Folk (1994), however, found no effect of depth on attentional measures.

What has produced these variations in distance effect results? Hoffman and Mueller (1994) suggested that what is crucial is the presence of placeholder objects marking the positions of the to-be-attended location. In Experiments 11 and 12 the possible location of a target was marked by a small square – the intended purpose of which was to attempt to draw participants to the usefulness of the box showing that, for example, targets will only occur within the frame (i.e. on 'Bothin' trials), or outside of the frame (i.e. on 'Bothout' trials). Cave and Bichot (1999) suggest such landmark squares may act as distractors. Participants need to focus their attention on these squares in order to determine when (or if) one of them changes into a target. Without the squares participants could focus their attention more diffusely over the entire display, or, more probably since they know where to expect targets, in and around the area of the frames. A second possibility, is that the position markers (or placeholders, or landmarks) are perceived as objects in their own right and that attention is drawn to them rather than to the frames.

Experiment 13 used the same stimuli and procedure as in Experiment 11, except that the two small target position markers no longer appeared with the cue and box frames. It was predicted that, in their absence, participants would make use of the box frames to focus their attention and that this would produce a different pattern of results to those found in Experiment 11 and 12. More explicitly, if attention acts on a grouped or object representation, and if being part of an object, or inside of a box frame perceptual group when attention has been focussed on this grouping is advantageous, then it would be likely that targets appearing within a box frame would produce fastest responses (i.e. in Bothin trials) and targets occurring outside of the frame would be slower (i.e. Bothout trials). Additionally, targets in the 4x6 degree box frames (i.e. TP:In, OP:Out, TP:Out, OP:In trials) would have slowest RTs since the target location is less predictable than in the Bothin and Bothout conditions. TP:In, OP:Out might be expected to produce faster RTs than TP:Out, OP:In.

The standard (e.g. as found in Experiments 11 and 12) SOA and Cue Validity effects would also be expected in this experiment.

4.4.2 Method

Participants

Nine participants (four females and five males), aged between 22 and 48 participated in one practice session lasting approximately 2 minutes, and two experimental sessions each lasting approximately 30 minutes.

Two participants had not previously taken part in a reaction time experiment, the remaining 7 had participated in at least one such study.

The participants were undergraduates, postgraduates, and staff at the University of Durham. All were volunteers and were paid at a rate of £5.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment

Apparatus, Stimuli, Design and Procedure

The apparatus, stimuli, design and procedure were identical to those used in Experiment 11 with the exception that no position markers appeared on the screen. The central fixation was replaced by a cue (Valid, Neutral, or Invalid) and a box frame (one of four different types: Bothin, TP:In, OP:Out, TP:Out, OP:In, Bothout).

As in Experiment 11, following an SOA of 100, 500, or 1000 ms, a target appeared either 2 degrees to the left or 2 degrees to the right of fixation. The participant's task was to respond as quickly as possible with a single key press to the onset of the target.

4.4.3 Results

Reaction Times (RTs) faster than 100 ms were discarded as anticipations and RTs greater than 1500 ms were also eliminated from the analysis since they were regarded as a lapse in the participant's attention, or indicated that they had taken a rest.

The mean reaction times (RTs) were calculated for each of the 9 participants under the four 'frame' conditions, for Invalid (I), Neutral (N), and Valid (V) trials at each of the 3 SOAs (i.e. 100, 500, 1000 ms). (See Table 4.3 showing means for each condition.)

A three-factor repeated measures ANOVA was performed. There were four levels of the first factor: Box frame (Bothin, TP:In, OP:Out, TP:Out, OP:In, Bothout); three levels of the second factor: Cue validity (Invalid, Neutral, and Valid); and three levels of the third factor: SOA (100, 500, and 1000).

As is apparent from Table 4.3 and Figure 4.5, the results show a clear effect of the Cue Validity manipulation. The ANOVA produced a significant Cue Validity main effect ($F(2,16) = 34.8$, $p<0.0001$). Valid cues produced fastest responding (mean RT = 354 ms), Neutral cues intermediate levels of responding (mean RT = 379 ms), and Invalid cues the slowest responses (mean RT = 390 ms). Pairwise comparisons showed significant differences between each level of Cue Validity (to at least $p=0.03$).

Table 4.3 Experiment 13: Table of RT means and associated Costs and Benefits for each Box Frame type, Validity, and SOA

	Box Frame											
	Bothin			TP:In, OP:Out			TP:Out, OP:In			Bothout		
Validity SOA	I	N	V	I	N	V	I	N	V	I	N	V
100	423	410	399	406	413	395	413	405	393	408	417	398
500	393	383	344	376	362	342	389	374	342	395	375	338
1000	371	352	324	358	339	323	378	360	319	371	359	330
Mean	396	382	356	380	371	353	393	380	351	391	384	355

Corresponding Costs (C) and Benefits (B)

		Box Frame				
		Bothin	TP:In, OP:Out	TP:Out, OP:In	Bothout	Mean
100	B	11	18	12	19	
	C	13	-7	8	-9	
500	B	39	20	32	37	
	C	10	14	15	20	
1000	B	28	16	41	29	
	C	19	19	18	12	
Overall	B	26	18	28	28	**25.0**
	C	14	9	14	8	**11.3**

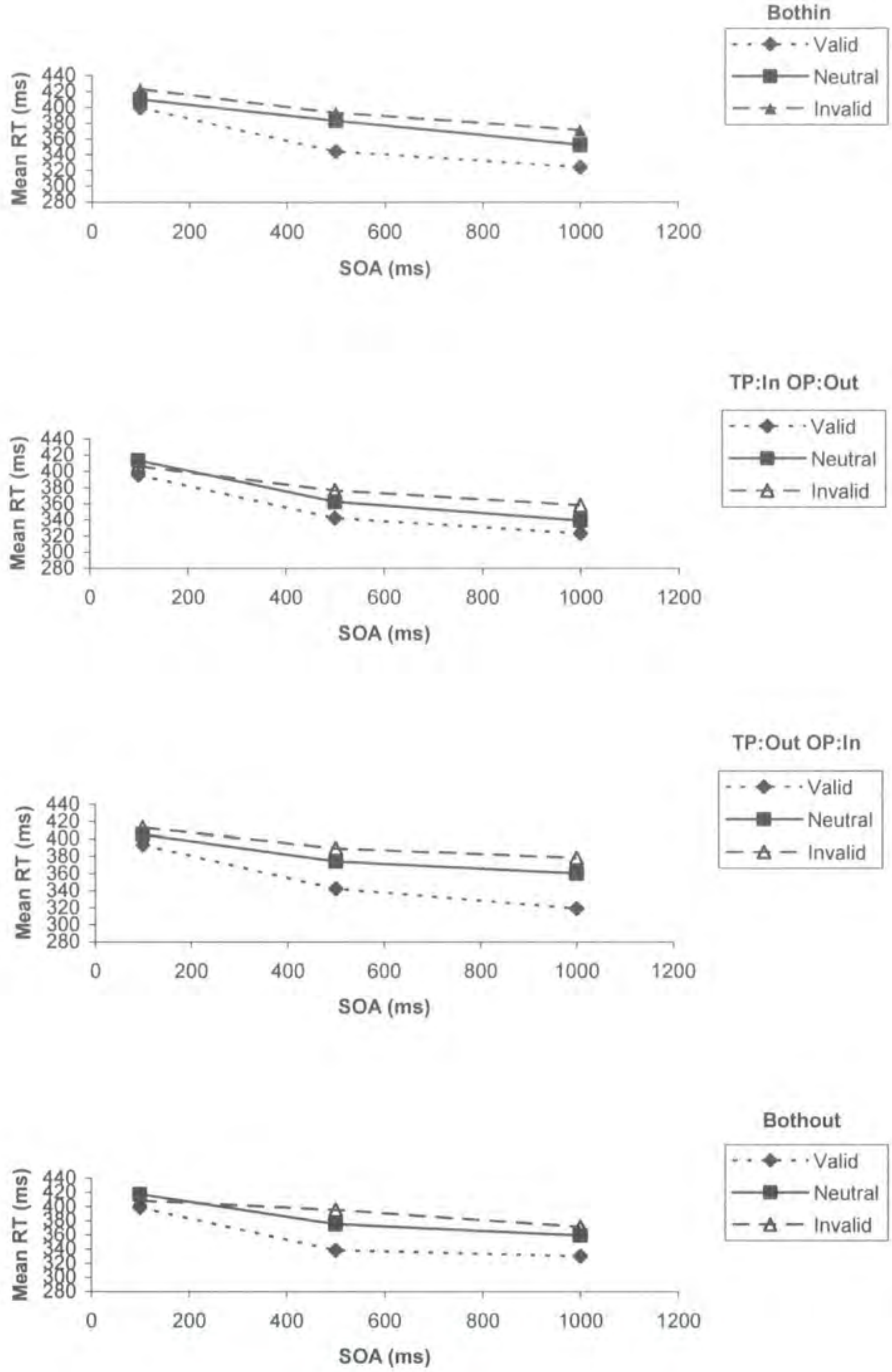


Figure 4.5 Experiment 13: Mean RTs for the four Box Frames at each SOA and Validity

The overall Benefits were similar for Bothin (26 ms), Bothout (28 ms), and TP:Out, OP:In (28 ms); and smaller for the remaining box frame condition, TP:In, OP:Out (18 ms). The overall mean Benefits were 25 ms. (See Table 4.3 for further breakdown of Benefits.)

The overall Costs were identical for Bothin and TP:Out, OP:In (both were 14 ms); Bothout and TP:In, OP:Out were similar at 8 ms and 9 ms respectively. The overall mean Costs here were 11.3 ms. (See Table 4.3 for further breakdown of Cost)

As in previous experiments, a significant main effect of SOA was found ($F(2,16) = 29.1$, $p<0.0001$). The optimum SOA in this experiment was 1000 ms: SOAs of 1000 produced a mean RT of 349 ms, as opposed to 368 ms at SOAs of 500, and 406 ms at SOA equal to 100. Pairwise comparisons significant differences between each level of SOA (to at least $p=0.015$).

SOA was also found to interact significantly with the Validity of the target ($F(4,32) = 7.363$, $p<0.0001$) (See Figure 4.6). In general, all trials showed a decrease in RT with increasing SOA, Valid trials producing the greatest and Invalid trials the least quickening of RT with SOA.

There was also a significant main effect of Box Frame ($F(1.310,10.479) = 6.386$, $p=0.023$). The TP:In, OP:Out condition produced fastest responding (mean RT = 368 ms); the TP:Out, OP:In condition second fastest (mean RT = 375 ms); the Bothout condition gave a mean RT of 376 ms; and the Bothin condition produced slowest RTs (mean RT = 378 ms). Pairwise comparisons revealed significant differences between TP:In, OP:Out and Bothin ($p=0.019$) and between TP:Out, OP:In and Bothout ($p=0.001$). None of the other comparisons was significant.

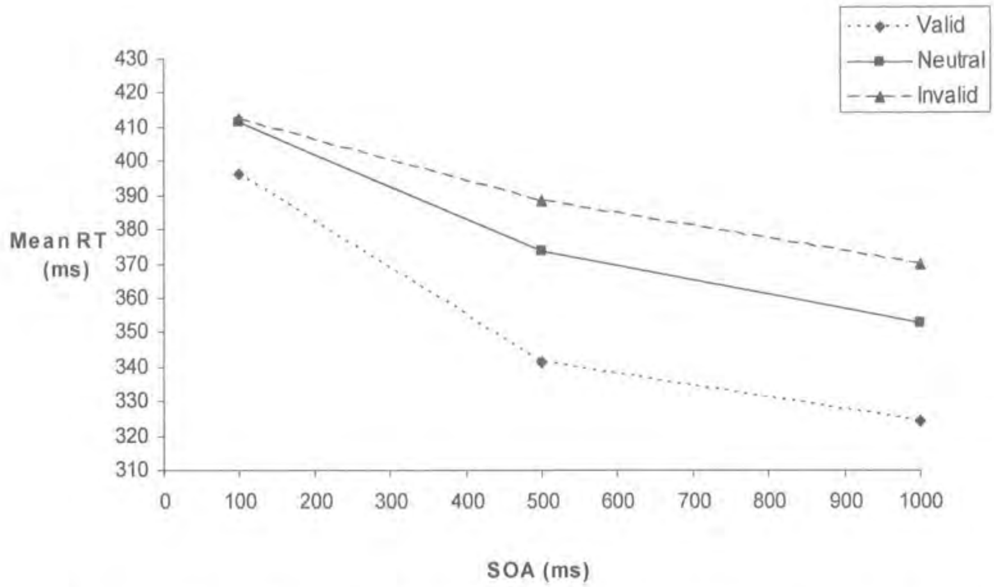


Figure 4.6 Mean RTs for Valid, Neutral and Invalid trials at each of the three SOAs

There were no other significant effects: The 2-way interaction of Box Frame x Cue Validity appeared to be approaching significance ($F(6,48) = 2.217$, $p = 0.0579$). Condition TP:In, OP:Out was apparently differently affected by the Cue Validity manipulation than were the other three conditions. (See Figure 4.7 below.)

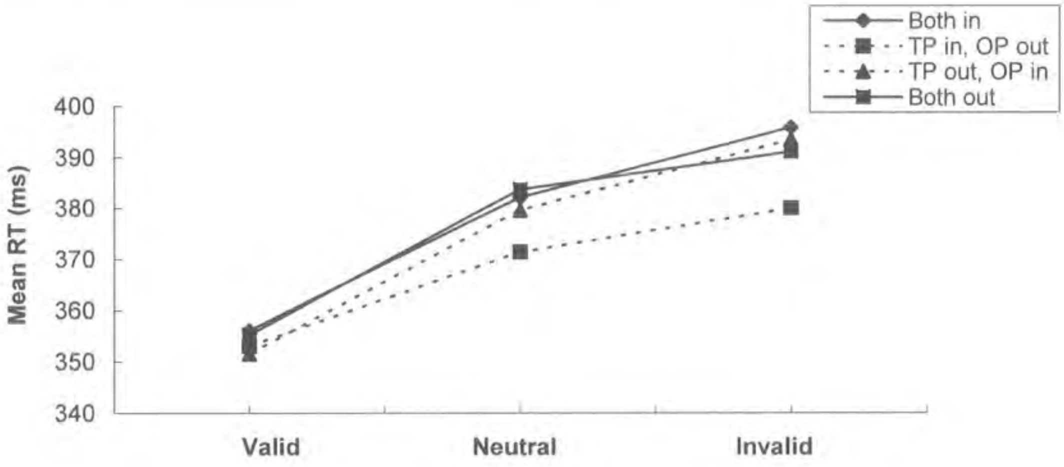


Figure 4.7 Mean RTs for Valid, Neutral and Invalid trials at each of three SOAs

The 2-way interaction of Box Frame x SOA was not significant ($F(6,48) = 1.439$, $p = 0.220$). The 3-way interaction (Box Frame x Cue Validity x SOA) was also not significant ($F(12,96) = 1.626$, $p= 0.097$).

4.4.4 Discussion

Experiments 11 and 12 both showed significant main effects for Cue Validity, SOA and a 2-way interaction between Cue Validity and SOA. This experiment also produced such results.

Intuitively and from the results of previous experiments (e.g. Downing & Pinker, 1985; Hoffman and Mueller, 1994) one might predict that the use of landmarks might aid detection, and indeed, response times were slightly slower in this experiment than in Experiment 11 (which included position marker/landmarks in addition to the box frames). But since different participants were used in the two experiments, this difference is small enough to be attributed to individual participant RT variation.

However, the overall Benefits found here were 25 ms, slightly larger than those found in Experiment 11 (where Benefits were 19 ms) and similar to those found by Posner, Nissen, and Ogden (1978). This is unsurprising since Posner et al's experiment also used no position markers. So, using a different measure, the lack of position markers, but the presence of a box frame, has altered the pattern of detection - their exclusion increased the Benefits of a Valid cue and decreased the Costs of an Invalid cue. (This latter result is not in line with Posner at al's experiment where 40 ms Costs were found vs. 11.3 ms Costs here.)

More interestingly and contrary to the results from Experiment 11, this experiment did produce a significant main effect of Box Frame. (This factor did not interact with SOA or Cue Validity.) It was proposed that if participants grouped the stimuli displayed, and if such grouping is beneficial, then this would result in fastest RTs for the Bothin condition and slowest RTs for the Bothout condition. It was further suggested that the other 2 Box Frame conditions (i.e. TP:In, OP:Out, TP:Out, OP:In) would bring about even slower RTs since target location would be more unpredictable.

However, the results did not support these predictions. TP:In, OP:Out produced fastest response times (mean = 368 ms), followed by TP:Out, OP:In (375 ms), Bothout (376 ms), and finally Bothin (378 ms). But when looking at the pairwise comparisons, the only significant differences are between TP:In, OP:Out and Bothin, and TP:In, OP:Out and Bothout trial types. Figure 4.7 (Validity x Box Frame condition diagram) helps illustrate this finding.

Although there was no significant 2-way interaction between Box Frame and Cue Validity, the main difference between the TP:In, OP:Out condition and the other three conditions appears to lie with the Neutral and, in particular, with the Invalid values. Valid trials produced comparable results across the four Box Frame conditions.

It is difficult to explain the pattern of results obtained. Neither the RTs nor a comparison of the Costs and Benefits elicit a clear explanation, although a number of possibilities were considered.

The results cannot be explained by the differences in spatial separation between cue and target, or box frame and target, as these were kept constant.

Nor can they be accounted for by an explanation based on predictability of targets, or of the other/non-target position, in relation to the box frame - Bothin and Bothout conditions should fare better than the $4x6^0$ box frames, which have relatively unpredictable locations in terms of the target, or 'other position' being inside or outside of the box. For example, Bothout, Bothin, and TP:Out OP:In produce greatest Benefits (28 ms, 26 ms, and 28 ms respectively), followed by TP:In OP:Out (18 ms). However, Costs are greatest for Bothin (14 ms) and TP:Out OP:In (14 ms) and smallest for Bothout (8 ms) and TP:In OP:Out (9 ms). And RTs are fastest for the two $4x6^0$ box frames.

Perhaps differences in the exogenous cueing effects might account for differences? Although participants were asked to use the endogenous cue, the nature of the randomisation procedure meant that different trial types produced different amounts of additional stimulation from the frames appearing and disappearing. This might lead to different levels of attentional focussing. Castiello and Umiltá (1990) found that increasing box size decreased response time benefits. Goldsmith and Yeari (2003) propose that when attention is widely spread, object-based attention may be obtained, but that these effects may be reduced when attention becomes narrowed. The box frames used in Experiment 13 may have caused differences in the ways participants allocated their attention: more widely in Bothin trials and more narrowed in Bothout trials, and intermediate amounts for the two remaining trial types. If this is the case then one might expect a pattern of responding that reflects this (e.g. Bothout greatest benefits or fastest RTs, the 4x6 degree box frames producing intermediate effects, and Bothin smallest benefits of longest RTs). However, the results do not show this simplistic patterning which may reflect Goldsmith and Yeari's notion that attentional effects are an interplay between goal-directed and stimulus-driven factors.

Despite the fact that no unambiguous or simple explanation of the results seems possible, nevertheless the exclusion of the position markers has had some effect on the orienting of attention to the different trial types, indicating at least some possibility of object-based or grouping effects.

4.5 Experiment 14

Endogenous cueing with targets and box frames in a peripheral location using a detection task

4.5.1 Introduction

The results from Experiments 11 and 12 showed that participants' response times were affected by changes in SOA and in Cue Validity, but were apparently unaffected by the nature of the visual stimuli in close proximity to the target and non-target locations (i.e. the box / line frame).

It has been demonstrated that we can focus attention more narrowly in foveal regions and ignore closer distractors in this central area than we can in the periphery (e.g. Humphreys, 1981). Downing and Pinker (1985) showed that the costs of endogenous cues are generally greater for more foveal stimuli and for smaller retinal separations and Henderson and Macquistan (1993) showed a similar gradient model of spatial distribution using exogenous cues; although Posner (1978) did not find such differences. It is possible, therefore, that in Experiments 11 and 12, because the targets were presented in the central 4^0 of the visual field, participants narrowly focussed their attention and were able to ignore the box / line frames and were not processing the stimuli presented as a group.

(There is some disagreement as to whether object-based attention does depend on the level of focussing or spatial extent of attention. Lavie and Driver (1996) suggested that object-based effects are not found when attention is narrowly focussed, but may be found when attention is diffuse. However, more recently, others have shown object-based attention with restricted focus (e.g. Egly, Driver, & Rafal, 1994; Lamy and Egeth, 2002; Law and Abrams, 2002).

Furthermore, although the original intention was to demonstrate object-based attention using endogenous cueing, the procedure used does involve a certain amount of peripheral stimulation. Theories of attention that involve eye movements and exogenous cueing (e.g. Rizzolatti, Riggio, Dascola, & Umiltá, 1987; Rizzolatti, Riggio, & Sheliga, 1994) might predict that no effects would be found in this foveal region since it was unnecessary for participants to make (or plan to make) an eye movement. Moving the box frames to a more peripheral location may invoke such motor programmes, and hence result in a different attentional effect – one that may involve incorporation of a grouped array.

Experiment 14 was a partial replication of Experiment 11, except that the box frames were 'doubled up' and moved into the periphery. That is, pairs of identical boxes appeared centred at 10 degrees to the left and to the right of fixation. Participants were again asked to make a single response to the appearance of a target that could be in one of four locations: 8 and 12 degrees to the left or right of the central fixation point. These locations were framed by either a Bothin type of box, or by a Bothout box. (For reasons of economy, the other two conditions TP:In, OP:Out and TP:Out, OP:In were omitted from the design.)

The aim of this experiment was to see if attentional processes work differently in peripheral locations; to see if grouping stimuli will affect response times to the targets. It was predicted that if there is grouping, being Inside a box frame (condition Bothin) would speed response times to targets relative to being Outside a box frame (condition Bothout). It was also expected that RTs would decrease with increasing SOA and that the usual Cue Validity result would be found. Finally, it might be expected that increasing eccentricity would increase response times. However, as already discussed in the Introduction to Experiment 3, there has been some considerable debate over this issue with the now more generally accepted view that attention is not analogue in nature, but may jump to locations with no time cost. The prediction then would be that there will be no overall different between RTs to near and far targets, however there may be a difference in the size of Costs and Benefits if the idea of a spatial gradient holds true: the separation between the central symbolic cue and Near targets (8^0) is smaller than the retinal separation between cue and Far targets (i.e. 12^0), which may result in greater Costs and Benefits to Near than to Far targets. And finally, a spatial gradient would also predict smaller Costs and Benefits in this experiment than in Experiment 11 (for the comparable conditions) since the visual angle of target used in the latter study was 2^0.

4.5.2 Method

Participants

Nine participants (6 females and 3 males) aged between 22 and 45 participated in one practice session lasting approximately 3 minutes, and one experimental session lasting approximately 30 minutes.

Four participants had not previously taken part in a reaction time experiment. The remaining 5 had participated in at least one such study.

The participants were undergraduates, postgraduates, and staff at the University of Durham. All were volunteers and were paid at a rate of £5.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment

Apparatus

The experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh Performa 630, with stimuli presented on an Apple MultipleScan 1705 Display screen.

The keyboard space bar was used as the response. The participant placed their chin on a rest fixed to produce a 57cm viewing distance from the screen. The room was dimly illuminated by one of the room-lights.

Design

The design was a within-subjects design with 4 independent variables: Box Frame (2 levels: Bothin, Bothout); Cue Validity (3 levels: Invalid, Neutral, and Valid); SOA (3 levels: 100, 500, 1000 ms); and Target eccentricity (2 levels: Near (targets at 8^0 eccentricity) and Far (targets at 12^0 eccentricity)). The dependent variable was the mean response time to detect a target.

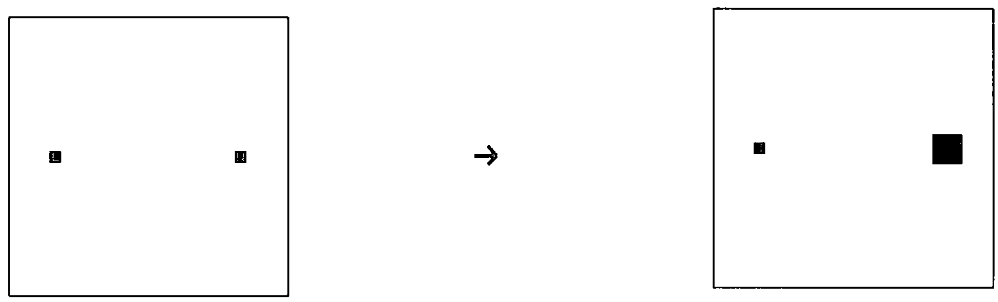
Procedure

The procedure was identical to that used in Experiment 11 with the exception that after an interval varying between 400 to 1000 ms, the fixation was replaced by a cue; two boxes, and four position markers also appeared on the screen. (See Figure 4.8 for examples of the stimuli.)

The four position markers (0.2^0 filled black squares as in Experiment 11) indicated the 4 possible locations of the target: 12^0 to the left of the central fixation point (Far Left), 8^0 to the left of the central fixation (Near Left), 12^0 to the right of the central fixation (Far Right), and 8^0 to the right of the central fixation (Near Right).

Just as in Experiment 11, the cue which replaced the fixation point could be one of three types: a Valid (V) cue, an Invalid (I) cue, or a Neutral (N) cue. If a cue was Valid (and not a catch trial), the target appeared with 80% probability in either the Near or Far locations in the direction of the arrow cue and was equally likely to be in either location. If the cue was Invalid (and not a catch trial), the target appeared with 20% probability in either the Near or Far locations in the opposite direction (or side) to the cue (again it was equally likely to be in either of these locations).

Bothin box frames showing a target appearing in the Far Right location following a Valid arrow cue



Bothout box frame showing a target appearing in the Near Left location following a Neutral cue

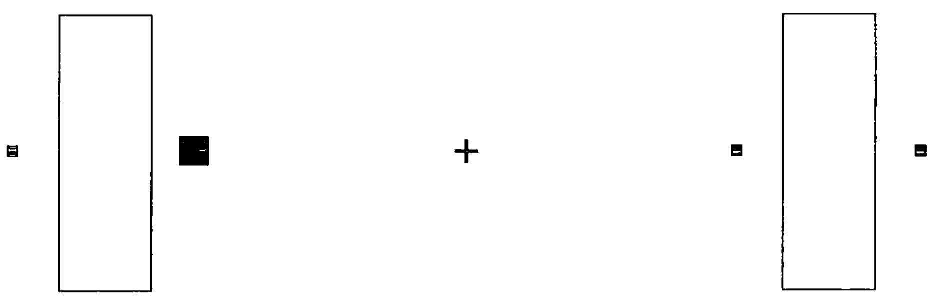


Figure 4.8 The two box frame types used in Experiment 14 – cues presented centrally, but pairs of Bothin or Bothout box frames along with position markers and target presented in the periphery

If the Neutral cross appeared, the target appeared with equal probability in any of the four possible target locations - unless no target appeared.

As previously mentioned, in addition to the 4 position markers, and cue replacing the fixation point, two box frames appeared on the screen. These could either be two Bothin box frames, or two Bothout box frames. (See Figure 4.8 above.)

The cue, position markers, and boxes appeared for one of three durations: 100, 500, or 1000 ms (i.e. three SOAs). Following this a target (a 0.6^0 filled black square as in Experiment 11) appeared either to the right (Near Right or Far Right locations), or to the left (Near Left or Far Left locations) of fixation, replacing one of the 4 position markers.

The participant's task was to respond as quickly as possible with a single key press to the onset of the target.

The stimuli were presented in two experimental blocks, where each block contained 96 Valid trials, 120 Neutral trials, 24 Invalid trials and 12 catch trials for each of the two box frames. These were randomised before presentation.

4.5.3 Results

Reaction Times (RTs) faster than 100 ms were discarded as anticipations and RTs greater than 1500 ms were also eliminated from the analysis since they were regarded as a lapse in the participant's attention, or indicated that they had taken a rest.

The mean reaction times (RTs) were calculated for each of the 9 participants under the two 'box frame' conditions (Bothin and Bothout); for Cue

Validity (Invalid, Neutral, and Valid trials); at each of the 3 SOAs (i.e. 100, 500, 1000 ms); and at the 2 target eccentricities (Near and Far). (See Table 4.4.)

A four-factor repeated measures ANOVA was performed: There were two levels of the first factor: Box Frame (Bothin, Bothout); three levels of the second factor: Cue Validity (Invalid, Neutral, and Valid); three levels of the third factor: SOA (100, 500, and 1000); and two levels of the fourth factor: Target Eccentricity (Near, Far)

Table 4.4 Mean RTs for the two Box Frames, at each Validity, SOA, and Eccentricity

Bothin

	Valid			**Neutral**			**Invalid**		
SOA	100	500	1000	100	500	1000	100	500	1000
Target Eccentricity									
Near	443	375	365	447	422	381	495	409	443
Far	463	411	374	474	405	396	475	429	395

Bothout

	Valid			**Neutral**			**Invalid**		
SOA	100	500	1000	100	500	1000	100	500	1000
Target Eccentricity									
Near	442	382	364	455	418	394	429	388	407
Far	453	390	386	465	416	395	472	432	404

Main effects:

As can be seen from Table 4.4, the results show a clear effect of the Cue Validity manipulation. The ANOVA produced a significant Cue Validity main effect ($F(2,16)=30.883$, $p<0.0001$). Valid trials produced the fastest responding (mean RT = 404 ms), Neutral trials an intermediate level of responding (mean RT = 422 ms) and Invalid trials the slowest responses (mean RT = 432 ms). Pairwise comparisons showed significant differences between Valid and Neutral trials (p<0.001) and between Valid and Invalid trials (p<0.001), but not between Neutral and Invalid trials (p=0.178).

The overall mean Benefits, comparable to those found in Experiments 11, were 18 ms. (See Table 4.5 for Cost/Benefit Analysis for Experiment 14.) The overall mean Costs here were 9 ms, less than half those found in the two earlier experiments (i.e. Experiments 11 and 12). Looking more closely at the breakdown of Costs and Benefits it is noticeable that overall Near targets produce greater Benefits than Far targets (24.3 ms vs. 12.3 ms respectively) but no noticeable difference between Costs (9.0 ms vs. 9.3 ms respectively). However, breaking this down into the two conditions, or box frame types, it is apparent that for Bothin trials Costs and Benefits were larger for Near than for Far targets; but for Bothout trials there was a slightly different patterning: Near targets produced greater Benefits than Far targets, but smaller Costs (in fact the results show negative Costs.)

Table 4.5 Cost Benefit Analysis for Experiment 14

		SOA					
Bothin		100	500	1000	mean		mean (Near & Far)
Near	Benefits	4	47	16	22.3	Benefits	15.7
	Costs	48	-13	62	32.3	Costs	20.2
Far	Benefits	11	-6	22	9		
	Costs	1	24	-1	8		

Bothout		100	500	1000	mean		mean (Near & Far
Near	Benefits	13	36	30	26.3	Benefits	21.0
	Costs	-26	-30	13	-14.3	Costs	-1.8
Far	Benefits	12	26	9	15.7		
	Costs	7	16	9	10.7		

Overall (Bothin & Bothout)

	Near	Far	mean
Benefits	24.3	12.3	18.3
Costs	9.0	9.3	9.2

A significant main effect of SOA was found ($F(1.467,11.734) = 26.234$, $p<0.0001$). (See Table 4.4 showing Mean RTs.) As the SOA increases, so the RT decreases. The optimum SOA in this experiment was 1000 ms. (An SOA of 1000 produced an overall mean RT of 392 ms, as opposed to an overall mean RT of 407 ms at an SOA of 500 ms, and an overall mean RT of 459 ms at an SOA of 100 ms.) Pairwise comparisons showed significant differences between each of the SOA levels (to at least $p=0.04$).

There was a significant main effect of the Target Eccentricity manipulation ($F(1,8) = 16.8$, $p = 0.0034$). As target eccentricity increased, so RT increased. The overall RT means for Near (8^0) targets was 414 ms and for Far (12^0) targets this was 424 ms.

The Box Frame also produced a significant main effect ($F(1,8) = 12.71$, $p = 0.007$). The overall mean for the Bothin condition being 422 ms and the overall mean for the Bothout condition being 416 ms. That is, participants were slower to respond to targets when they appeared within a box, than when they appeared outside of a box.

<u>2-way Interactions:</u>

The Box Frame and Cue Validity 2-way interaction was significant ($F(2,16) = 5.074$, $p = 0.020$). Figure 4.9 (below) shows that mean RTs are similar for Valid and Neutral trials for both Bothin and Bothout conditions. The Invalid trials showed a clear difference between the two conditions: Bothin producing longer RTs than Bothout.

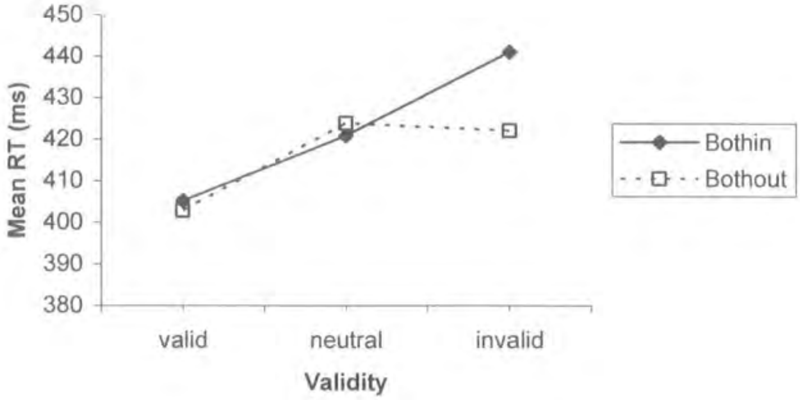


Figure 4.9 Mean RTs to Valid, Neutral, and Invalid trials for Bothin and Bothout box frame conditions

The Cue Validity and SOA 2-way interaction was significant (F(4,32) = 2.785, p = 0.0431). Figure 4.10 (below) shows that in general Valid, Neutral and Invalid RTs decrease with increasing SOA, but by differing amounts.

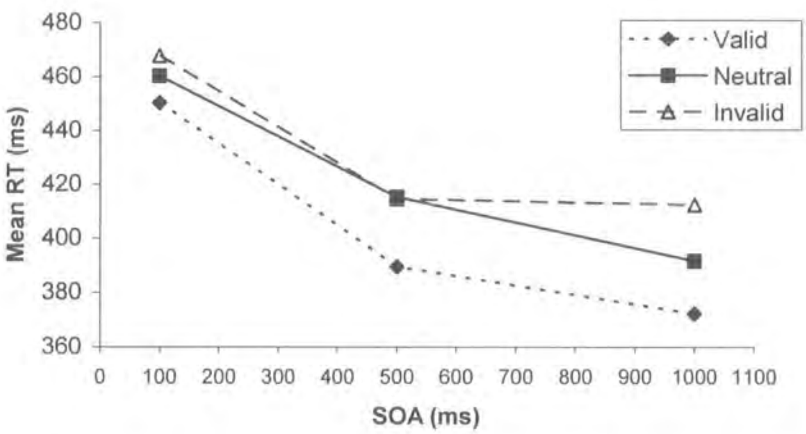


Figure 4.10 Mean RTs to Valid, Neutral, and Invalid trials at varying SOAs

The 2-way interaction between Cue Validity and Target Eccentricity was significant ($F(2,16) = 4.579$, $p = 0.027$). Figure 4.11 (below) shows that RTs to Valid, Neutral and Invalid trials generally increase with increasing eccentricity of target; Valid trials were more affected by increases in target distance than Neutral and Invalid trials.

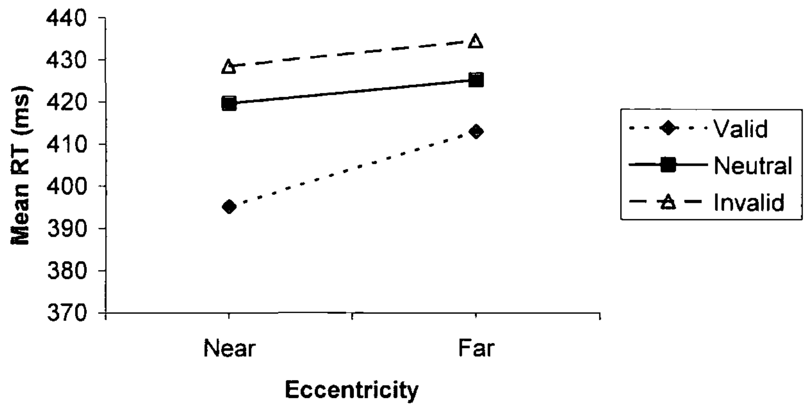


Figure 4.11 Mean RTs to Valid, Neutral, and Invalid trials at Near and Far target locations

The SOA and Target Eccentricity 2-way interaction was also significant ($F(11.187,9.492) = 5.233$, $p = 0.042$). Figure 4.12 (below) shows that these SOA RTs were differentially affected by changes in eccentricity. As SOA increased RTs were less affected by eccentricity increases.

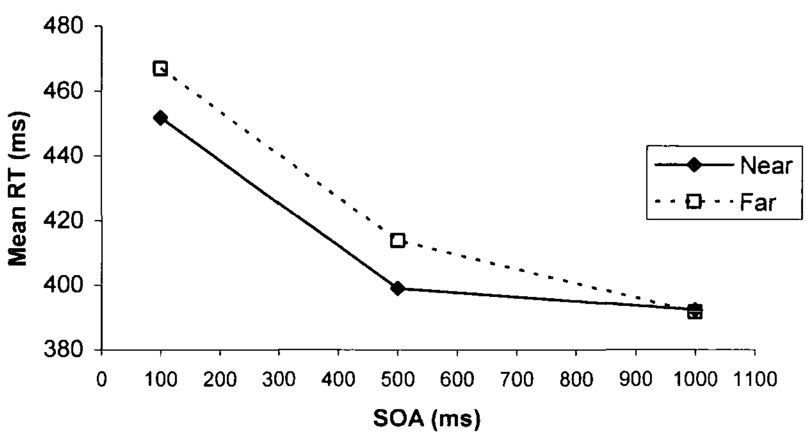


Figure 4.12 Mean RTs to targets at Near and Far locations at varying SOAs

The two remaining 2-way interactions were not significant: The Box Frame x SOA showed no significant differences between RTs for different SOAs and conditions (F(2,16) = 1.485, p = 0.256). (See Figure 4.13 below.)

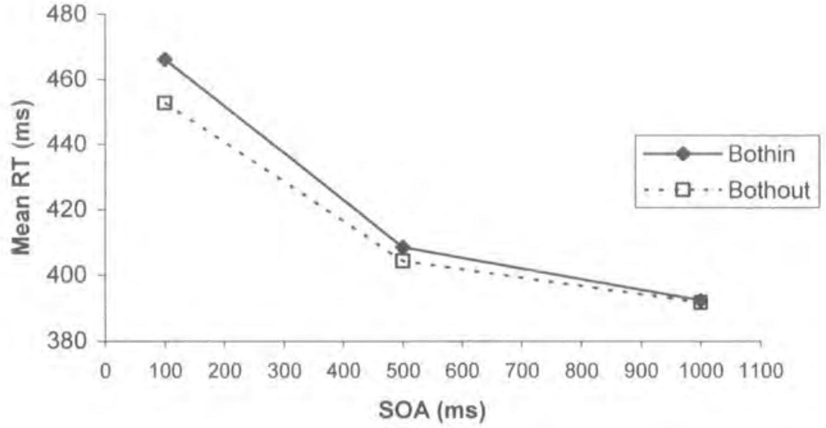


Figure 4.13 Mean RTs for Bothin and Bothout box frame conditions at varying SOAs

Figure 4.14 below shows the mean RTs for the Box Frame x Target eccentricity interaction. Although there appear to be differences between Near and Far targets in the two conditions this did not reach significance (F(1,8) = 2.401, p = 0.16).

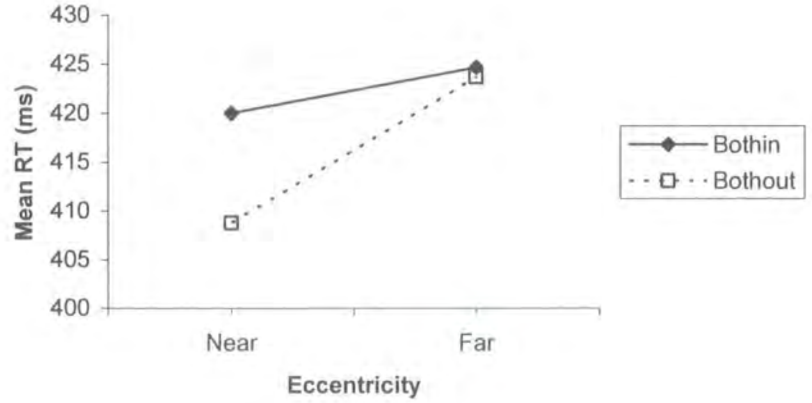


Figure 4.14 Mean RTs for Bothin and Bothout box frame conditions at Near and Far target locations

3-way interactions:

Two 3-way interactions produced significant results: Box Frame x Cue Validity x Target Eccentricity (F(1.072,8.572) = 6.135, p = 0.035) (See Figure 4.15 below) and Cue Validity x SOA x Target Eccentricity (F(4,32) = 6.831, p = 0.0001) (See Figure 4.16 below).

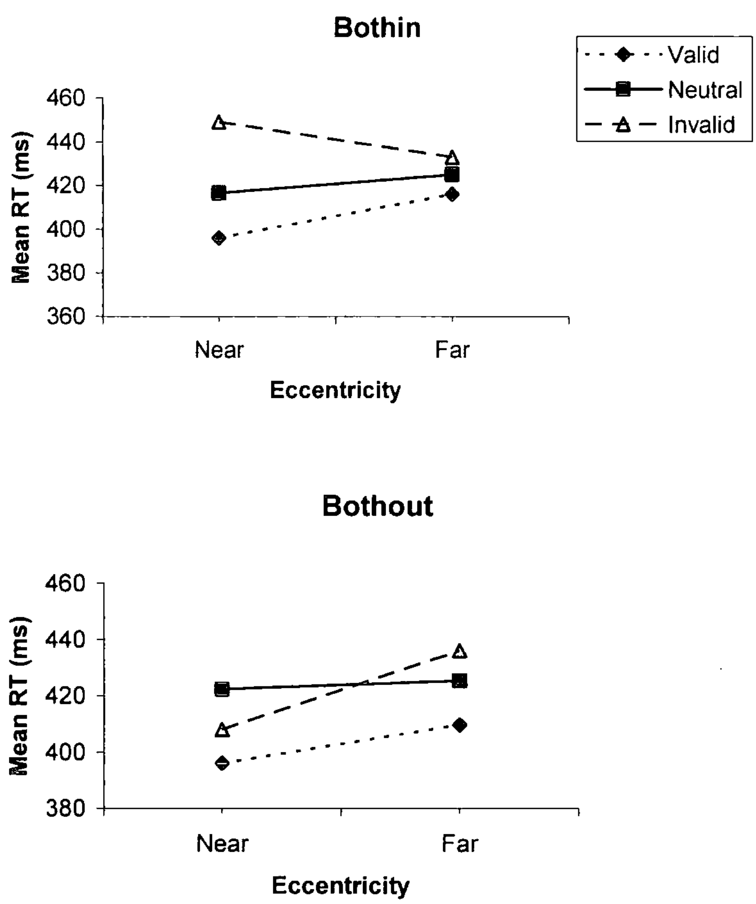


Figure 4.15 The two diagrams above together show the significant Box Frame x Cue Validity x Target Eccentricity 3-way interaction: Mean RTs for Bothin and Bothout box frame conditions at Near and Far target locations for Valid, Neutral and Invalid trials

The main difference between these two diagrams (Figure 4.15 above) lies with the Invalid trials. (Valid and Neutral conditions produce relatively similar patterns of RTs across the two box-frame conditions.) For the Bothin style of box frame, Invalid trials show decreasing RTs from Near to Far targets, whereas for the Bothout frame, Invalid trials show an increase in RTs.

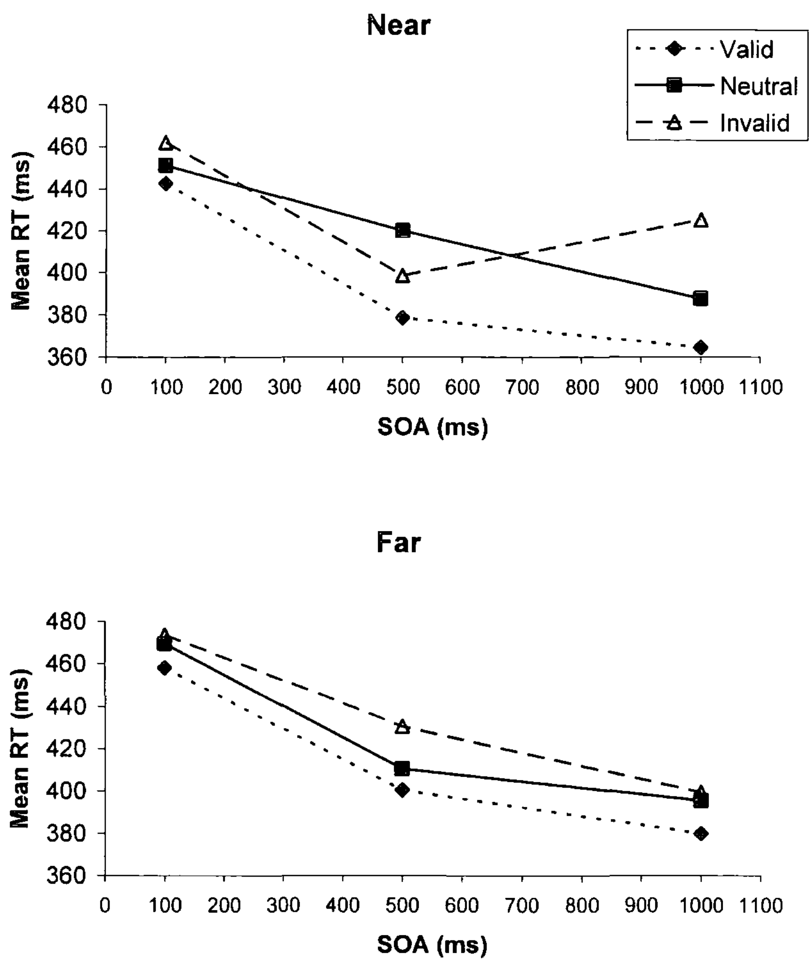


Figure 4.16 Two diagrams together showing the significant Cue Validity x SOA x Target Eccentricity 3-way interaction: Mean RTs for Near and Far target locations for Valid, Neutral and Invalid trials at three SOAs.

The main impact of this 3-way interaction between Cue Validity x SOA x Target Eccentricity appears to be on Invalid Near RTs which increase at an SOA of 1000 ms in comparison to the more usual decrease with SOA shown by the Invalid Far RTs in the lower graph.

The remaining two 3-way interactions yielded non-significant findings: Box Frame x Cue Validity x SOA ($F(1.864,14.91) = 0.519$, $p = 0.593$) and Box Frame x SOA x Target Eccentricity ($F(1.075,8.602) = 0.641$, $p = 0.456$).

4-way interaction:

The 4-way interaction (Box Frame x Cue Validity x SOA x Target Eccentricity) was significant ($F(4,32) = 2.905$, $p = 0.0370$).

4.5.4 Discussion

As in the three earlier experiments, Experiment 11, 12, and 13, this study produced a significant main effect of SOA. Reaction times decreased with increasing SOA. (See also Discussion section of Experiments 11 and 12).

A significant main effect of Cue Validity was also found. Valid trials producing fastest RTs and Invalid trials slowest RTs. The overall Benefits found here (18.3 ms) were comparable to those found in Experiment 11 (18.6 ms), however the overall costs were drastically reduced: 9.2 ms in this experiment versus 22 ms and 20 ms found in Experiment 11 and 12 respectively (although Experiment 13 had 11.3 ms Costs).

It would be misleading however, to look simply at the overall means since those produced by the two box frames differed markedly.

Benefits for condition Bothin were 15.7 ms (made up of 22.3 ms for Near targets and 9 ms for Far targets) and those for Bothout were 21 ms (26.3 ms for

Near; 15.7 ms for Far). So, overall Benefits were larger for Bothout trials and for Near targets. This eccentricity effect is one that would be predicted by some spatial gradient models of attention: the angle between Near targets and the cue is less than that between Far targets and the cue which should produce greater Benefits for the less eccentric targets. (However, notice that the Benefits for Near targets in this Experiment were greater than those of Experiment 11 in the comparable conditions, where the cue-target separation was 2^0. The reduction in box frame variability might possibly account for the greater Benefits found in this Experiment.)

Costs for condition Bothin were 20.2 ms (made up of 32.3 ms for Near targets and 8 ms for Far targets) and those for Bothout were -1.8 ms (-14.3 for Near and 10.7 for Far). So for Bothin the patterning of Costs was as for Benefits: larger for Near than for Far targets. For Bothout types of frame, there were smaller (in fact negative) Costs for Near than for Far targets. This does not fit the patterning predicted by a simple spatial gradient viewpoint. (The later discussion on Box frame effects also relates to these Cost-Benefit findings.)

There was also a significant main effect of target eccentricity. As eccentricity increased, from 8 to 12 degrees, so response times increased. This interacted (2-way) significantly with SOA and Cue Validity, but not with Box Frame. However, there was a significant 3-way interaction between Eccentricity, SOA and Box Frame, a significant 3-way interaction between Eccentricity, SOA and Cue Validity and a significant 4-way interaction. Taking these into consideration, the main impact of Eccentricity seems to be with Cue Validity and SOA: Valid Near targets are responded to faster than Valid Far targets, but mainly at SOAs of 100 and 500 ms, but not at 1000 ms. (See Figure 4.11 showing 2-way interaction between Cue Validity and Eccentricity.) Also Invalid Near targets' RTs increased at the longest SOA in comparison to Invalid Far targets (See Figure 4.16 showing 3-way interaction between Cue Validity, SOA, and Eccentricity)

Finally, contrary to Experiments 11 and 12, this experiment produced a significant main effect of Box Frame. It is apparent that target detection in the periphery can be affected by varying the visual stimuli 'surrounding' it. However, it was predicted that the Bothin condition would produce faster RTs than the Bothout condition and the converse was found.

The main impact of this Box Frame manipulation, and of the Experiment, seems to be with Cue Validity: Valid and Neutral trials were not greatly affected by altering Box Frame. However, Invalid trials showed large differences (see Figure 4.9 showing the 2-way interaction between Box Frame and Cue Validity). Participants were slower to respond to trials occurring on the uncued side if they occurred within a box frame than if they occurred outside of a box frame. This also interacted significantly with eccentricity - but this seems to be due to Valid trials being differentially affected by eccentricity, rather than by Invalid trials: Valid Near targets were responded to faster than Valid Far targets (as mentioned earlier).

Finally incorporating the three-way interaction of Validity, Eccentricity and Box Frame (see Figure 4.15) which highlights further the effect of the Invalid cue; the RTs increase in the Bothout (lower graph) for Invalid trials, but decrease in Bothin (upper graph).

So, to try to summarise the findings: there were the usual main effects of SOA and Validity, and also main effects of the Box Frame and Eccentricity. And the most apparent effects of the interactions were: firstly, that Valid Near targets were responded to faster than Valid Far targets, but mainly at the two earlier SOAs (i.e. 100 and 500 ms); and secondly that Invalid trials were faster with Bothout frames than with Bothin, but only for Near targets.

An attempt at explaining these results is as follows: on seeing an arrow cue, the participant moves their attention in the direction of the cue using a global final position strategy (i.e. they move their attention to the mid-point between the two position markers in the direction of the cue). If this movement takes time (debatable – see earlier comments on movement of attention), and if the target appears before attention has arrived at its destination, then Valid Near targets would be responded to more quickly than Valid Far targets. If attention has already arrived at the midpoint destination, then both Valid Near and Valid Far target responding would be the same since targets are equidistant from the point of attention. If an Invalid trial takes place, the participant has to shift attention to the opposite hemifield to detect the target. The Near targets are detected more speedily for Bothout box frames than for Bothin since there are no distractors en route. The Far targets do have distracting stimuli under both types of box frame condition. It is not possible to say whether this Invalid-Near/Far target effect is a consequence of object-based attention, or some form of perceptual grouping, since it is possible that, for example, it might be an effect of having to cross boundaries/vertical lines. It would be interesting to follow this experiment up with one looking specifically at such boundary crossings.

Although one is wary of basing theories on subjective descriptions, participants in this experiment reported that the Bothout condition 'felt easier' than the Bothin condition on Invalid trials. They reported perceiving the Bothin stimuli as a group, but that this made the detection of the change from position marker to target more difficult rather than easier. Although it was originally suggested that being part of an object might aid detection, it has been noted in previous studies that if target and distractors are grouped, or perceived as an object, then the amount of interference from the distractor stimuli would be greater (e.g. Baylis & Driver, 1991; Driver & Baylis, 1989; Kramer & Jacobson, 1991; Pomerantz & Pristach, 1989). If the position markers are viewed as distractors, then this would account for the finding that Bothout targets were generally more easily detected than Bothin.

So, although the results are not conclusively in favour of an object-based view, this experiment did nevertheless yield differences due to the Box Frame manipulation which could be accounted for by some form of perceptual grouping of frame and distractors.

Finally, it should be noted that care must be taken when attempting to make direct comparisons between this experiment and the two earlier experiments in this chapter. Although the box frames used here were identical to those used in Experiment 11, the visual stimulation was 'doubled' (i.e. a single box / line frame was presented in the first two experiments, whilst 2 box frames were presented here). It is inevitable that the onset of two sets of boxes in the periphery would have different effects to a single frame box occurring centrally and that these effects may not just be due to a foveal-central shifting of stimulation.

4.6 General Discussion

The four experiments presented in this chapter attempted to demonstrate object-based attentional representation using endogenous cueing in a detection task. Previous experiments showing object-based effects have often successfully used exogenous cueing and divided visual attention studies, or where stimuli are moving objects. Few have used an endogenous cueing methodology. If it is the case that the different modes of attentional cueing can both lead to object- and location-based forms of attention, rather than exogenous leading to object-based and endogenous leading to location-based, then this would have important implications for models of attentional orienting.

All four experiments in this chapter showed similar significant main effects due to the SOA and Validity manipulations, as well as significant interactions between SOA and Validity. (See Table 4.6 for summary of results.) This implies that the endogenous cues were being used by the participants as in other comparable studies with detection tasks.

Table 4.6 Summary of results for the 4 endogenous cueing experiments (i.e. Experiments 11-14)

	Experiment 11 (4 different box frames)	Experiment 12 (4 different line frames)	Experiment 13 (no position markers)	Experiment 14 (peripheral boxes)
Box Frame (Box)	ns	ns	sig	sig
Validity (Val)	sig	sig	sig	sig
SOA	sig	sig	sig	sig
Eccentricity (Ecc)	-	-	-	sig
Box x Val	ns	ns	ns	sig
Box x SOA	ns	ns	ns	ns
Box x Ecc	-	-	-	ns
Val x SOA	sig	sig	sig	sig
Val x Ecc	-	-	-	sig
SOA x Ecc	-	-	-	sig
Box x Val x SOA	ns	ns	ns	ns
Box x Val x Ecc	-	-	-	sig
Box x SOA x Ecc	-	-	-	ns
Val x SOA x Ecc	-	-	-	sig
4-way interaction	-	-	-	sig

The results from Experiments 11 and 12 showed identical results with only small variations in reaction time measures between the two experiments. They seemed to indicate that participants, despite subjective reports, were making no use of the 'objects' in aiding (or hindering) detection of targets since there was no effect of the box frame manipulation, nor any interaction with the other independent variables. The results could have been accounted for by the unblocked, randomised procedure employed, by the effects of landmarks, by the foveal positioning of stimuli in these experiments, and by the strategic control adopted by participants which made it unnecessary for them to encode the stimuli as objects or even as a grouped array.

Experiment 13 addressed the issue of the presence of the position markers (or landmarks/placeholders) within the display. Removing these target location markers clearly affected the results. The RTs were generally slower here than in the previous two experiments; Benefits were larger and Costs were smaller. There was an effect of the type of box frame used, but the pattern of results was not as expected. It was not possible to explain effects in terms of target predictability or attentional focusing, but nevertheless the results do indicate at least a possibility that participants were grouping the stimuli in some fashion and that this affected their attentional allocation.

Experiment 14 moved the box frame displays into a more peripheral location. Although only two different frame types were tested in this experiment, an interesting and complex pattern of Costs and Benefits was produced which did vary with Box frame type. It was originally thought that being part of an object (inside a box) might aid detection and being outside of an object would increase response times. However, the results suggest the opposite: Bothout trial targets were in general more easily detected than Bothin. If, as it seems may have been the case, the position markers were viewed as distractors and these were grouped together with the boxes and target, this would result in greater interference and produce the findings in this experiment. This account might also help partially explain the results from the previous experiment where longer RTs were reported for Bothin than for Bothout trials. (However the results from the remaining trial types continue to be difficult to explain.)

The next chapter continues to use an endogenous cueing methodology, but changes the task demands so that instead of making a simple detection response participants were required to make an 'inside/outside' judgement. It was thought that if it was necessary for participants to use all the visual stimuli provided, then perhaps a concomitant change of mechanism may also result.

Chapter 5

Endogenous cueing with targets and frames in central and peripheral locations using a decision task

5.1 General Introduction

As mentioned in the Introduction to Experiment 11, there is a growing consensus that both space-based and object-based forms of attentional representation coexist. The task for researchers now could be said to be that of finding the conditions or moderators of location-based, and in particular, object-based attention.

Recent work looking at attentional capture by feature singletons and control settings (e.g. Folk, Remington, & Johnston, 1992, 1993; Folk, Remington, & Wright, 1994; Müller, Reiman, & Krummenacher, 2003; Theeuwes, 1994; Turatto & Galfano, 2001; Yantis, 1993) has high-lighted the importance of looking at the interaction between goal-driven and stimulus-directed attention. Also, Vecera and Farah (1994) note that "if subjects do not need to represent objects as objects but merely detect the onset of some target, then...detection may be accomplished using relatively low-level array representations." (p 153)

The two experiments described in this chapter changed the task demands from those of a simple detection used in the last chapter, to one of a location judgment: Participants were asked to indicate whether the targets appearing during the experiment occurred inside or outside of the box frames.

Experiment 15 replicates Experiment 11 using identical stimuli and Experiment 16 replicates and extends Experiments 14; both use a two-alternative-forced choice decision task. It was predicted that the alteration of the participants' goals will cause a change in the nature of responding, perhaps reflecting a change in the nature of the perceptual organisation of representation on which attention operates.

5.2 Experiment 15

Endogenous cueing with targets and frames in a central location using a decision task

5.2.1 Introduction

The results of Experiment 11 showed both Cue Validity and SOA effects, but no effect of the Box Frame manipulation. It was suggested that the nature of the task demands, coupled with the use of a randomised, rather than a blocked, presentation of the Box Frames, may have called upon a particular type of attentional mechanism.

Recent studies have suggested that top-down or goal-directed settings may influence the nature of attentional representation. For example, Folk, Remington, and Johnston (1992, 1993) and Folk, Remington, and Wright (1994) concluded that the task goals set in the experiment could define the features eliciting an attentional shift.

Awh, Matsukura, and Serences (2003) looked at the effects of biased competition during covert spatial orienting. The findings showed that it was neither changes in signal enhancement, nor the spatial distribution of attention that affected results, but the probability of interference of distractors. In other words, they concluded that that top-down control settings can determine where spatial attention is directed and how it impacts on visual processing.

Although no research using symbolic cueing and such inside/outside judgements is available as a comparison, it seems plausible that changing the nature of the response required by the participant may elicit a concomitant change in responding, and hence in attentional effects, in the box frame situation.

Experiment 15 replicated Experiment 11 except that rather than making a single key press response to the appearance of a target, participants were required to make a location judgement: one key was pressed when the target appeared inside a box frame, and another key pressed when the target appeared outside a box frame.

As the cue, in addition to its 'attentional validity' role, acts as a temporal warning signal, SOA results similar to those found in the earlier experiments would be predicted in this study: As the time between the cue and target increases, the decision time should decrease.

Since this was a 2AFC situation, one would clearly expect increased decision times in comparison to the RTs in detection studies, however if participants were induced into noticing the frame, perhaps using a different attentional mechanism, or neurological pathway, then the pattern of results would also be expected to vary. If the box frames are now perceived as some sort of perceptual unit, one might predict different decision times, and different attentional cueing effects arising, to targets occurring inside and outside of a box.

If being contained within the box/perceptual unit is advantageous (the previous experiments have shown that sometimes it is and sometimes it is not), then the Bothin conditions would be expected to produce fastest decision times with greatest Benefits and smallest Costs; the Bothout condition would produce the slowest decision times with smallest Benefits and greatest Costs; for the remaining two conditions, TP:In, OP:Out would produce greater Benefits and smaller Costs than TP:Out, OP:In, although the specific prediction for these conditions in relation to Bothout is unclear, since the target locations for these two box frames are much less predictable.

However, an alternative prediction arising from distraction studies and from the results of Experiment 14 might be that Bothout and possibly TP:Out, OP:In trials would benefit the decision making process since they have targets occurring outside of the box frame grouping. In these trials there would presumably be less interference caused in these conditions than in Bothin and possibly TP:In, OP:Out since in these trials targets were inside the perceptual groupings.

Evidence from search studies also mostly suggests an advantage for 'outside' over 'inside' targets. For example, Quinlan, Findlay, and Brown (unpublished) in research investigating topological relationships, found performance to detect a dot located outside of a bounded contour was consistently better than locating a dot within a bounded contour. Also, Treisman and Gormican (1988) found search asymmetries where inside dot targets gave rise to steeper search time slopes than outside dot targets. However, one-item displays (as opposed to those with 6 or 12 items) produced an anomalous result: responses were faster for inside than for outside dot targets.

A final possibility is that if box size is the important variable, and by implication, attentional focus size, though the results of Experiments in Chapter 3 suggest otherwise, then one might predict a pattern of effects mirroring that of increasing frame size (i.e. Bothout, TP:Out, OP:In = TP:In, OP:Out, followed by Bothin).

5.2.2 Method

Participants

Nine participants (5 females and 4 males), aged between 19 and 48 participated in one practice session lasting approximately 5 minutes, and 2 experimental sessions each lasting 20 minutes. Seven of the participants were right-handed and 2 were left-handed.

Three participants had not previously taken part in a reaction time experiment. The remaining 6 had participated in at least one such study.

The participants were undergraduates, postgraduates, and staff at the University of Durham. All were volunteers and were paid at a rate of £5.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment.

Apparatus

This experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh G3, with stimuli appearing on a ProNitron 17/200 monitor.

The keyboard characters ‘y’ and ‘h’ were used as the response keys.

The participant placed their chin on a rest fixed to produce a 57cm viewing distance from the screen.

The room was dimly illuminated by one of the room-lights.

Stimuli

The experimental stimuli used were as described in Experiment 11.

Design

The design was a within-subjects design with 3 independent variables: Box Frame (4 levels: Bothin, TP:In, OP:Out, TP:Out, OP:In, Bothout); Cue Validity (3 levels: Invalid, Neutral, and Valid); and SOA (3 levels: 100, 500, and 1000 ms).

Despite the confound of box size (i.e. the fact that a large box - Bothin frame type - or small box - Bothout frame type - allowed for greater predictability of responding) it was nevertheless decided to keep all 4 levels of the Box Frame independent variable.

The dependent variable was the mean time to make an Inside / Outside judgement about a target.

Procedure

The procedure was identical to that of Experiment 11 with the exception that participants were required to make a manual choice response to the target. If the target appeared inside a box frame, one of the response keys was pressed, and if the target appeared outside of a box frame, a different key was pressed.

Four of the participants used their preferred hand to indicate an 'Inside' response; the remaining five used their preferred hand to indicate an 'Outside' response. All participants rested their right forefinger on the 'h' key and their left forefinger on the 'y' key.

5.2.3 Results

The mean decision judgement times (which for ease will be abbreviated to RTs) were calculated for each of the 9 participants under the four 'box frame' conditions (Bothin; TP:In, OP:Out; TP:Out, OP:In ;and Bothout); for Cue Validity (Invalid, Neutral, and Valid trials); and at each of the 3 SOAs (i.e. 100, 500, and 1000 ms).

RTs faster than 100 ms were discarded as anticipations and RTs greater than 2500 ms were also eliminated from the analysis since they were regarded as a lapse in the participant's attention, or indicated that they had taken a rest.

Two three-factor repeated measures ANOVAs were performed. There were four levels of the first factor: Box Frame (Bothin; TP:In, OP:Out; TP:Out, OP:In; and Bothout); three levels of the second factor: Cue validity (Invalid, Neutral, and Valid); and three levels of the third factor: SOA (100, 500, and 1000 ms).

The initial ANOVA looking at percentage correct responses was carried out. The second analysis looked at the RT correct data; that is where errors (i.e. where an incorrect judgement of 'inside/outside' had been made) had been eliminated from the calculations.

Percentage correct / Accuracy Analysis

In general, participants were very accurate at making 'Inside/Outside' judgements. The overall mean was 94% correct.

The ANOVA showed a significant Box Frame main effect ($F(3,24) = 3.709$, $p = 0.0253$). Slightly reduced accuracy was obtained when the target appeared inside the box frame: the Bothin condition producing a mean of 93.2% correct scores and the TP:In, OP:Out condition a mean of 93.3%. When the target was outside the box frame, accuracy was greater: the TP:Out, OP:In condition yielded a mean accuracy of 95.6% and the Bothout condition a mean of 95.8%.

Table 5.1 Mean accuracy scores (mean % correct) for Invalid (I), Neutral (N), and Valid (V) trials at each SOA for each of the four Box Frames

Box Frame

	Bothin			TP:In, OP:Out			TP:Out, OP:In			Bothout		
Validity SOA	I	N	V	I	N	V	I	N	V	I	N	V
100	86.1	90.6	95.8	93.1	95.0	96.2	94.4	96.9	94.4	97.2	96.3	93.0
500	91.7	94.4	96.9	86.1	92.7	96.2	93.1	96.7	94.8	100.0	95.0	95.4
1000	91.7	94.2	97.9	88.9	94.7	97.2	98.6	96.3	95.5	94.4	96.7	93.8
	89.8	93.0	96.9	89.4	94.1	96.5	95.4	96.6	94.9	97.2	96.0	94.1
Mean	93.2			93.3			95.6			95.8		

There was also a significant 2-way Box Frame x Cue Validity interaction ($F(6,48) = 3.268$, $p = 0.0089$). Table 5.1 giving mean percentage accuracy shows the nature of this interaction: where the target position is inside the box frame (i.e. in the Bothin and TP:In, OP:Out conditions) accuracy decreases from Valid to Neutral to Invalid trials; where the target appears outside of the box frame (i.e. in the Bothout and TP:Out, OP:In conditions) accuracy is marginally greater in the Neutral and Invalid than in the Valid trials.

None of the other main effects or interactions was significant.

Decision Reaction Time analysis

The reaction times produced in this experiment were on average more than 300 ms slower than the RTs found in Experiment 11.

Table 5.2 Experiment 15: Table of RT means and associated Costs and Benefits for each Box Frame type, Validity, and SOA

	Box Frame											
	Bothin			TP:In, OP:Out			TP:Out, OP:In			Bothout		
Validity	I	N	V	I	N	V	I	N	V	I	N	V
SOA												
100	732	724	699	758	744	733	735	739	676	739	700	727
500	615	635	561	690	701	604	688	676	609	612	623	571
1000	562	597	549	664	655	608	634	647	634	731	574	565
Mean	636	652	603	704	700	648	685	687	640	694	632	621

Corresponding Costs (C) and Benefits (B)

		Box Frame				
		Bothin	TP:In, OP:Out	TP:Out, OP:In	Bothout	
100	B	25	11	63	-27	
	C	8	14	-4	39	
500	B	74	97	67	52	
	C	-20	-11	12	-11	
1000	B	48	47	13	9	
	C	-35	9	-13	157	Mean
Overall	B	49	52	47	11	**40**
	C	-16	4	-2	62	**12**

As seen from Table 5.2 and Figure 5.1, the results show a Cue Validity effect. The ANOVA produced a significant main effect for this variable ($F(2,16) = 3.760$, $p = 0.0424$). The overall Cue Validity means were 628 ms for Valid trials, 668 ms for Neutral trials, and 680 ms for Invalid trials. Pairwise comparisons revealed a significant difference between Valid and Neutral trials ($p=0.042$), but no significant difference between Valid and Invalid trials, nor between Neutral and Invalid trials. (I.e. Benefits were significantly affected, but Costs were not.)

The overall mean Benefits were 40 ms and the overall mean Costs here were 12 ms, but as seen in Table 5.2 there was great variation in these scores across the Box Frame conditions (although there was no significant 2-way interaction between Box Frame and Cue Validity).

The ANOVA produced a significant SOA main effect ($F(2,16) = 28.552$, $p<0.0001$). As the SOA increases, so the RT decreases. The optimum SOA in this experiment was 1000. The overall RT SOA means were 725 ms at an SOA of 100, 632 ms at an SOA of 500, and 618 ms at an SOA of 1000. The pairwise comparisons showed significant differences between SOAs of 100 ms and 500 ms ($p<0.001$), and 100 ms vs. 1000 ms ($p<0.003$); but no significant difference between 500 ms vs. 1000 ms SOA.

There was a non-significant interaction between Cue Validity and SOA ($F(4,32) = 2.222$, $p = 0.0887$).

The ANOVA of RTs for correct responses produced a significant Box Frame main effect ($F(3,24) = 5.760$, $p = 0.0041$). Participants were faster to make an 'Inside/Outside' judgement in the Bothin condition (mean RT = 630 ms), next fastest in the Bothout condition (mean RT = 649 ms), next fastest in the TP:Out, OP:In condition (mean RT = 671 ms), and slowest in the TP:In, OP:Out condition (mean RT = 684 ms).

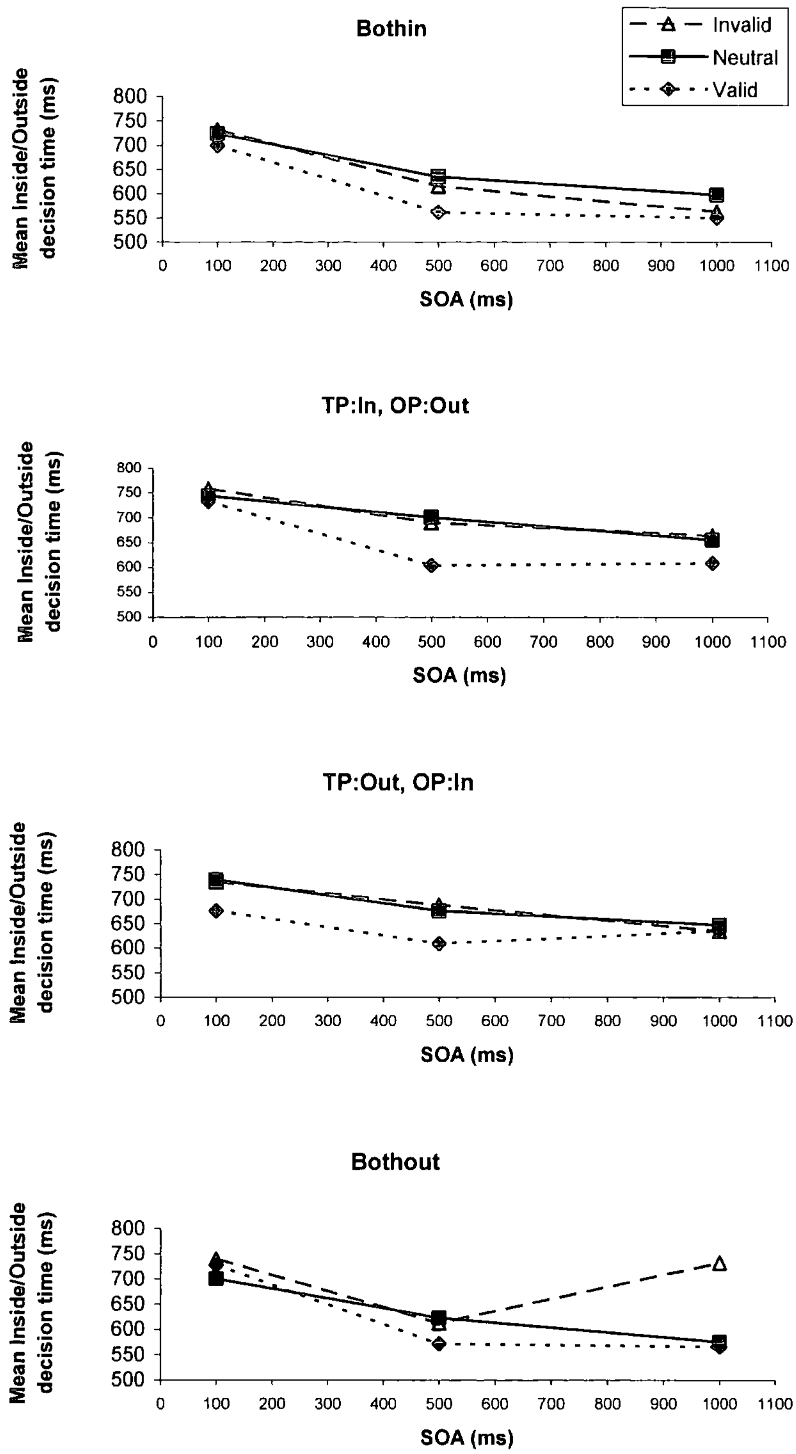


Figure 5.1 Experiment 15: Mean RTs for the four Box Frames at each SOA and Validity

Comparing the two conditions with the same size box frame, it appears that when the box size is 4x6 degrees, participants respond faster when the target is outside the frame. However, the largest, 6x6 degrees (condition Bothin), and thinnest, 2x6 degrees, (condition Bothout) box frames produce the fastest responses; the Bothin gave faster RTs than the Bothout condition. Pairwise comparisons showed a significant difference between Bothin and TP:In, OP:Out (p=0.009), but none of the other comparisons was significant.

The Box Frame x SOA interaction also produced a significant result (F(6,48) = 3.496, p = 0.0060). Three of the four conditions follow a similar pattern of RTs, where response times decrease with increasing SOA. However, the Bothout condition sees an increase in RT at an SOA of 1000 ms. This appears to be a result of the Invalid trials at this SOA. (See Figures 5.1 and 5.2 condition Bothout.)

The remaining 2-way and 3-way interactions were not significant: Box Frame x Cue Validity (F(6,48) = 2.108, p = 0.0696) and Box Frame x Cue Validity x SOA (F(12,96) = 1.612, p = 0.1008).

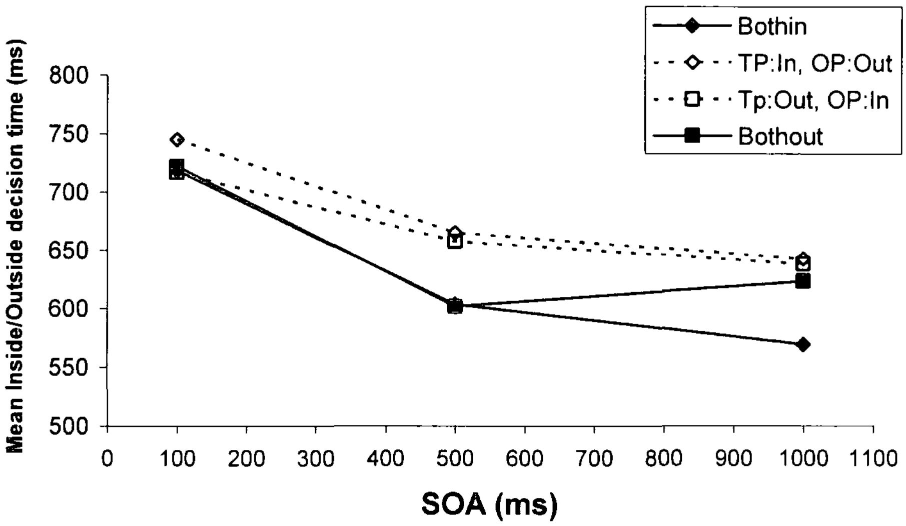


Figure 5.2 Mean Inside /Outside decision time (ms) for each of the four box frames at each of three SOAs.

5.2.4 Discussion

Accuracy – percentage correct analysis

Despite the surprising subjective difficulty of this task, the level of accuracy in this experiment was very high. There was a main effect of Box Frame where targets appearing Inside a Box Frame were responded to less accurately than targets appearing Outside a Box Frame. There was also a significant interaction of Box Frame with Cue Validity: accuracy for Inside targets was worse for Invalid trials.

Reaction Time Analysis

As predicted, overall RTs in this experiment were generally slower than those found in Experiment 11. This is as to be expected when comparing choice reaction time with simple detection reaction time.

Experiment 15 yielded the usual significant SOA main effect: as SOA increased so RTs decreased.

As in earlier experiments (e.g. Experiments 11, 12, 13, and 14), a Cue Validity effect was found. Valid trials giving fastest responses and Invalid trials the slowest. (The latter finding was particularly as a result of a large outlier in the Bouthout condition – see right hand column in Table 5.2 and lowest graph in Figure 5.1.) It is worth emphasizing here that this is a novel finding: the symbolic attentional cueing procedure clearly affected the results of these inside/outside judgements.

Unlike Experiment 11, a significant main effect of Box Frame was found here. As predicted, participants were fastest to make an Inside / Outside judgement in the Bothin condition. The Bothout condition was next fastest, followed by the two 4x6 degree box frame conditions: TP:Out, OP:In and TP:In, OP:Out. Indeed, participants commented on the fact that the TP:Out, OP:In and TP:In, OP:Out conditions 'felt harder' than the Bothin and Bothout conditions. On seeing the largest and smallest box frames participants could make preparations for their Inside / Outside response, whereas the 4x6 degree box frames required much 'closer scrutiny' since it was impossible to be certain in advance of the response required. In the light of these comments, it is not surprising that the TP:Out, OP:In and TP:In, OP:Out conditions showed slower RTs than the Bothout condition.

Overall Benefits (mean: 40 ms) were much larger than those found in Experiment 11 (mean: 19 ms). Although no significant interaction was found between Cue Validity and Box Frame, the Benefits and Costs were noticeably different across the Box Frame conditions. (See Table 5.2.)

Looking at the RT and Cost/Benefit analyses together, it is apparent that the two main findings are firstly that the introduction of an Inside / Outside decision has considerably affected the Valid vs. Neutral trials comparison (i.e. the Benefits) across all the box frames. The Benefits for conditions Bothin, TP:In, OP:Out , and TP:Out, OP:In were all hugely increased relative to those in Experiment 11 whereas Bothout Benefits were reduced. And secondly, although Costs varied across the box frames (they generally decreased for three of the four frame types), the main impact was on Costs for the Bothout condition. These increased from 16 ms in Experiment 11 to 62 ms in this experiment. (Bothout Invalid trials being particularly affected at 1000 ms SOA.)

A simple exogenous cueing of different attentional focus size / box size does not account for the findings, not does a distraction account. The explanation that best, although not completely, fits the data is one where the experimental stimuli are perceived as a perceptual unit, and being contained within that unit benefits Inside / Outside judgements. Had the TP:In, OP:Out and TP:Out, OP:In conditions not been included in the experiment, then this explanation might suffice. However, it is unclear why there might be such differences in Costs between Bothout and the 4x6 degree size frames.

If one looks at the visual 'information' presented around the area of the cue and target in, say, conditions TP:Out, OP:In and Bothout it is identical. The only difference is the amount to which the box frames extend to the side of the cue. It seems that, in this central area, attention has been more widely spread in condition TP:Out, OP:In than in the Bothout condition and this has led to decreased benefits and to increased costs in condition Bothout. This would not fit with a distraction hypothesis and a narrower focus should really lead to an increase in processing efficiency, not a decrease (see for example, Castiello & Umiltá, 1990; Egeth, 1977; Eriksen & St.James, 1985). So it is difficult to account for this finding.

On a different note, Tipper (2005) suggested that box frame conditions Bothin and Bothout could be considered as detection tasks since the appropriate response ('the target is In' and 'the target is Out' respectively) is known in advance of the target due to the nature of these particular box frames. It is plausible that participants could simply produce a correct response to the onset of the target without reference to the cue validity. In comparison, the box frame conditions TP:In, OP:Out and TP:Out, OP:In, could be considered as two-choice discrimination tasks since the appropriate response is not known in advance of the target. Furthermore, Tipper suggests that, if this is true, then separate analyses could be carried out for the two types of task within this experiment (i.e. Bothin and Bothout analysed separately from TP:In, OP:Out and TP:Out, OP:In) thereby clarifying the patterns emerging in the data.

In response to Tipper's suggestion, it is worthwhile noting that the box frames in this experiment were not blocked, that is, a fully randomised presentation of the four box frames, validity, and SOA manipulations was implemented. It was necessary, therefore, for the participants to take note of the box frame as it appeared, to be able to produce a correct response. If the task was merely perceptual in nature (as is suggested by Tipper for the Bothin and Bothout conditions) then one would not expect any effects of the validity manipulation. This was clearly not the case: there were clear benefits associated with the symbolic arrow cues. Nevertheless, it was thought worthwhile to complete two additional analyses. A summary of the findings is presented here (See Table 5.3 below).

Table 5.3 Summary of Experiment 15 combined analysis (i.e. all four box frame typed included), and separate analyses of two box frame condition groupings.

	4 Box Frame conditions analysed together	Bothin vs Bothout	TP:In, OP:Out vs TP:Out, OP: In
Main effects:			
Box Frame	**sig**	**ns**	**ns**
Cue Validity	**sig**	**sig**	**ns**
SOA	sig	sig	sig
Interactions:			
Box Frame x Cue Validity	**ns**	**sig**	**ns**
Box Frame x SOA	**sig**	**ns**	**ns**
Cue Validity x SOA	ns	ns	ns
Box Frame x Cue Validity x SOA	ns	ns	ns

The outcome of these analyses firstly emphasises the importance of the overall analysis: significant Box Frame effects (the main effect of Box Frame, as well as the interaction between Box Frame and SOA as described earlier in the Results) were apparent here but not in the found in the two additional analyses.

Secondly, the additional analyses confirm the cue validity findings for the Bothin/Bothout comparison (i.e. see significant main effect of Cue Validity and significant interaction between Box Frame and Cue Validity) and interestingly, also highlight the lack of validity effect for the TP:In, OP:Out and TP:Out, OP:In box frames. This further contradicts the suggestion of 'simple' perceptual processing occurring during this experiment!

Finally, significant results were found in the combined analyses that were not shown in the additional analyses and vice versa. This clearly highlights the importance of breaking down such analyses as well as taking the broader picture of the experiment as a whole.

To conclude: In general, the results of this experiment suggest that changing the task demands for identical stimuli produced a change in the pattern of response times to that seen in Experiment 11. A change in the visual properties of stimuli surrounding the target has no effect on simple RTs, but does affect Inside / Outside choice response times. Moreover, there were clear effects of the Cue Validity manipulation on this type of choice decision. By implication, it seems evident therefore that different task demands tap into different mechanisms. It is possible that the Box Frames in this experiment are perceived differently, that grouping may have occurred, or that a different 'stream' is in operation, bringing about a different pattern of responding. Further investigation would help clarify the nature of this mechanism and how a choice is made between different types of processing.

5.3 Experiment 16
Endogenous cueing with targets and frames in a peripheral location using a decision task

5.3.1 Introduction

The second experiment in this chapter draws together two earlier studies.

In experiment 14 it was found that moving the targets to be detected 8 and 12 degrees into the periphery brought about a Box Frame effect where one had not existed when stimuli were presented centrally (unless position markers were excluded). For economy, only two types of Box Frame were used in this experiment producing the surprising result that, generally, targets in the Bothout condition were detected faster than in the Bothin condition. A main effect of eccentricity was also present: response times rising with increasing target eccentricity.

In Experiment 15 the task demands were altered from the simple detection task used, for example, in Experiment 11, to an Inside / Outside judgement. Despite using identical stimuli, Experiment 15 showed an effect of Box Frame where Experiment 11 had not. In this choice response situation, participants were generally faster in the Bothin condition than in the Bothout condition. The TP:Out, OP:In condition was faster than the TP:In, OP:Out condition.

The aim of Experiment 16 was to ask participants to make Inside / Outside judgements to targets occurring in the periphery. All four box frame types were presented. It was expected that the SOA and Cue Validity results would be comparable to those found in the other endogenous cueing studies, in addition to an effect of target eccentricity. A box frame effect was also predicted. If the Inside / Outside judgement is the prevailing force, one might expect a pattern of results where the conditions followed the Bothin faster than Bothout faster than TP:Out, OP:In faster than TP:In, OP:Out pattern. If the 'shift to the periphery' mechanism prevails then a Bothout faster than Bothin result might be expected. (Conditions TP:Out, OP:In and TP:In, OP:Out were not included in Experiment 14, so no predictions about their effects will be made in relation to Experiment 14.) A final possibility is that the combination of the two task demands interacts and produces a different pattern altogether.

The design of this experiment is necessarily complex making plausible predictions for all the 2-way, 3-way, and 4-way interactions almost impossible. Nevertheless, it was still thought a worthwhile venture!

5.3.2 Method

Participants

Nine participants (3 females and 6 males), aged between 22 and 48 participated in one practice session lasting approximately 5 minutes, and two experimental sessions each lasting approximately 30 minutes.

Four participants had not previously taken part in a reaction time experiment. The remaining 5 had participated in at least one such study. One participant was withdrawn from the analysis because too many trials (n = 67) were classified as anticipations. Of the remaining 8 participants, 6 were right-handed and 2 were left-handed.

The participants were undergraduates, postgraduates, and staff at the University of Durham. All were volunteers and were paid at a rate of £5.00 per hour. All reported normal or corrected-to-normal vision.

Participants were briefed at the beginning of the experiment, but were not informed of the precise nature of the study until the debriefing session which followed the end of the experiment. No participants withdrew from the experiment

Apparatus

This experiment was controlled by an experiment generator package (SuperLab) run on an Apple Macintosh G3, with stimuli appearing on a ProNitron 17/200 monitor.

The keyboard characters 'y' and 'h' were used as the response keys.

The participant placed their chin on a rest fixed to produce a 57cm viewing distance from the screen.

The room was dimly illuminated by one of the room-lights.

Stimuli

The stimuli used were as described in Experiment 14 with the addition of two further conditions: TP: In; OP:Out and TP: Out; OP:In. (See Procedure for further details.)

Design

The design was a within-subjects design with 4 independent variables: Box Frame (4 levels: Bothin, TP:In, OP:Out, TP:Out, OP:In, and Bothout); Cue Validity (3 levels: Invalid, Neutral, and Valid); SOA (3 levels: 100, 500, and 1000 ms); and Target eccentricity (2 levels: Near (targets at 8^0 eccentricity) and Far (targets at 12^0 eccentricity).

As in Experiment 15 there was a confound of box size (i.e. Bothin and Bothout frame types allowed for greater predictability of responding). Despite this, it was again decided to keep all 4 levels of the Box Frame independent variable to enable some comparisons with earlier experiments.

The dependent variable was the mean time to make an Inside / Outside of the box judgement about the location of a target.

Procedure

In this experiment, as in Experiment 14, the central fixation was replaced by a cue (Valid, Neutral, or Invalid), a pair of Box Frames (4 different types: Bothin, TP:In, OP:Out, TP:Out, OP:In, Bothout), and four position markers 8 and 12 degrees to the left and right of fixation.

N.B. The position markers and target locations were always 8 and 12 degrees to the right and to the left of the screen centre / fixation point. Hence the Bothin and Bothout types of box were centred with respect to the position markers whereas the TP:In, OP:Out and TP:Out, OP:In boxes were not. A symmetrical pattern was chosen for the TP:In, OP:Out and TP:Out, OP:In conditions rather than the asymmetric version. (See Figure 5.3.)

Following an SOA of 100, 500, or 1000 ms a target appeared, either near or far to the right or left of fixation, replacing one of the 4 position markers.

The participant's task was one of a choice reaction time - a single key press ('h' or 'y') to the onset of this visual target, deciding whether the target was inside or outside of a box. The keyboard characters used ('h' and 'y') were counterbalanced across the participants: 'h' was always pressed with the right hand and 'y' with the left, but 4 of the participants (3 right-handers and one left-hander) indicated an 'inside' judgement with 'h' and an 'outside' judgement with 'y'. The other 4 participants (3 right-handers and one left-hander) indicated an 'inside' judgement with 'y' and an 'outside' judgement with 'h'.

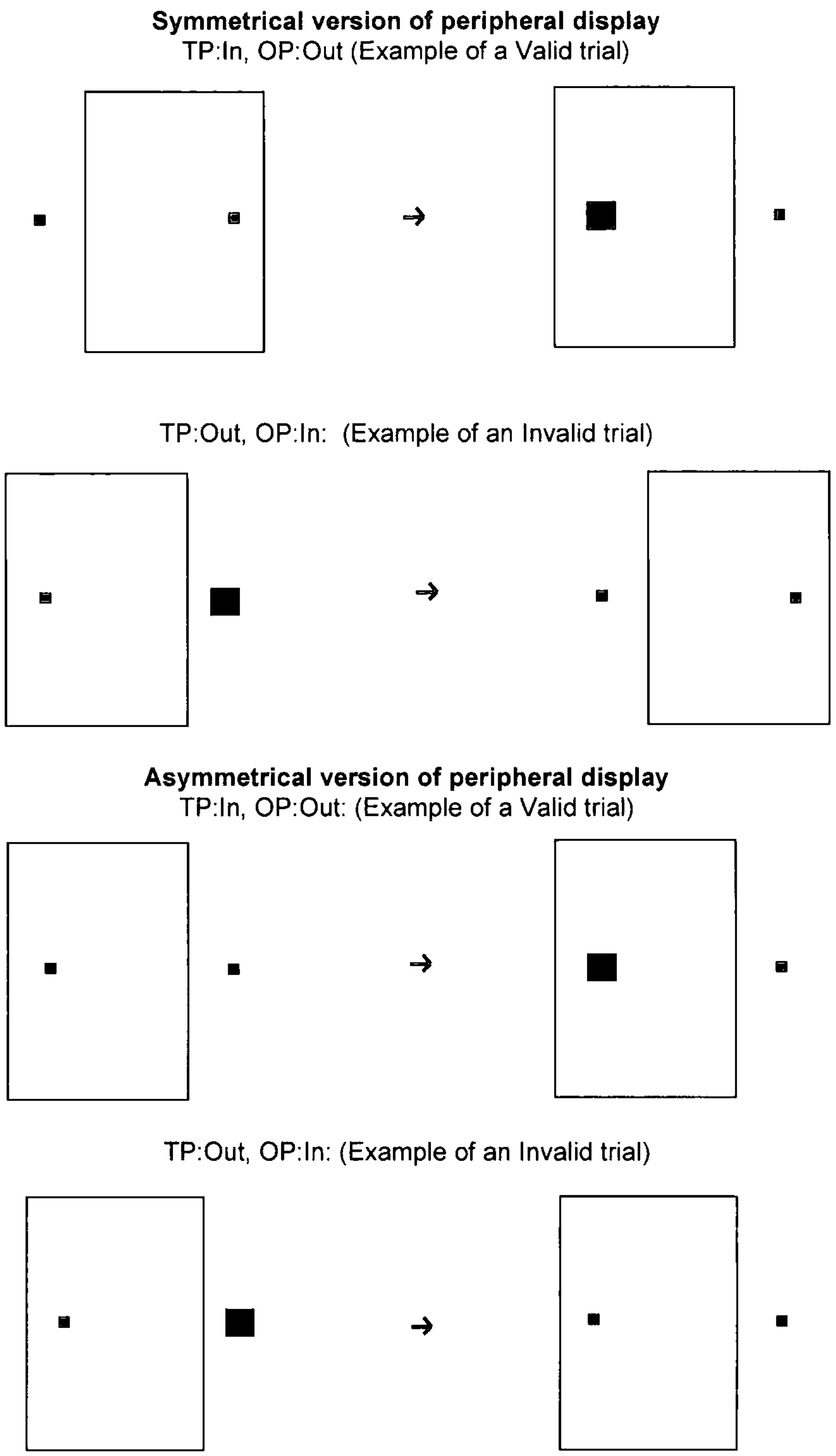


Figure 5.3 Examples of the symmetrical and asymmetrical arrangements of TP:In, OP:Out and TP:Out, OP:In box frames. The symmetrical arrangement was used in Experiment 16.

Participants were given three breaks during the 2 experimental sessions. Experimental trials had been randomised and the three breaks spread evenly throughout. Participants were also permitted to take additional rests when required. They were instructed not to respond whenever they needed a break and to allow at least 5 seconds to elapse before restarting the experiment by pressing the response key. These trials were discounted from the analysis

Otherwise the procedure was the same as that for Experiment 14.

5.3.3 Results

The mean decision reaction times (RTs) were calculated for 8 (out of the 9) participants under the four 'box frame' conditions (Bothin; TP:In, OP:Out; TP:Out, OP:In; Bothout); for Cue Validity (Invalid, Neutral, and Valid trials); at each of the 3 SOAs (100, 500, 1000 ms); and at the 2 target eccentricities (Near and Far).

Reaction Times (RTs) faster than 100 ms were discarded as anticipations and RTs greater than 2500 ms were also eliminated from the analysis since they were regarded as a lapse in the participant's attention, or indicated that they had taken a rest.

Two four factor repeated measures ANOVAs were performed.

There were four levels of the first factor: Box frame (Bothin; TP:In, OP:Out; TP:Out, OP:In; and Bothout); three levels of the second factor: Cue validity (Invalid, Neutral, and Valid); three levels of the third factor: SOA (100, 500, and 1000 ms); and two levels of the fourth factor: target eccentricity (Near, Far).

An initial ANOVA analysis looking at percentage correct responses is described. The second ANOVA looked at RTs of correct responses, that is where errors (i.e. where an incorrect judgement of 'inside/outside' had been made) had been eliminated.

Percentage correct / Accuracy Analysis

Overall, participants were extremely accurate at making Inside / Outside judgements, many making very few mistakes. The overall mean was 96% correct, slightly more accurate then Experiment 15 where there was 94% accuracy.

There were no significant Main Effects of Box Frame, Cue Validity, or SOA. Target Eccentricity, however, did produce a significant Main Effect ($F(1,7)= 14.685$, $p=0.0064$). As target eccentricity increased so accuracy also increased. The overall percentage correct means for Near targets was 95.9 and for Far target was 96.7.

Five of the six 2-way interactions were not significant. The remaining 2-way interaction, that of Box frame and Target eccentricity, was significant ($F(3, 21) = 3.805$, $p=0.0253$). None of the 3-way or 4-way interactions was significant.

Decision Reaction Time analysis

Main effects:

The ANOVA produced a significant Cue Validity main effect ($F(2, 14) = 9.557$, $p=0.0024$). The overall cue validity means show fastest responses (562 ms) for Valid trials, next fastest (591 ms) for Neutral trials, and slowest responding (621 ms) for Invalid trials. Pairwise comparisons revealed a significant difference between Valid and Invalid trials ($p=0.047$); the remaining comparisons (Valid vs. Neutral, and Neutral vs. Invalid) were not significant.

As shown in Table 5.5 the overall Benefits here were 29 ms and overall costs were 30 ms. (Although the Costs and Benefits do vary across the conditions the Cue Validity x Box Frame interaction was not significant – see below.)

Table 5.4 Mean RTs for the four Box Frames, at each Validity, SOA, and Eccentricity

	Valid			Neutral			Invalid		
SOA	100	500	1000	100	500	1000	100	500	1000
Bothin									
Near	601	480	452	601	515	498	626	529	538
Far	609	493	441	652	517	495	646	571	604
TP:In, OP:Out									
Near	633	539	568	657	610	615	656	643	683
Far	654	638	619	693	696	657	674	702	739
TP:Out, OP:In									
Near	653	574	593	663	608	616	716	656	704
Far	668	601	616	643	624	603	658	587	606
Bothout									
Near	601	465	458	623	503	512	615	640	499
Far	601	485	457	581	512	488	622	509	470

Table 5.5 Cost / benefit analysis for Experiment 16

	Box Frame				
	Bothin	TP:In,OP:Out	TP:Out, OP:In	Bothout	Mean
Benefits	33	47	8	25	29
Costs	40	28	28	23	30

The ANOVA produced a significant SOA main effect ($F(2, 14) = 29.473$, $p<0.0001$). As the SOA increases, so the RT decreases. The optimum SOA in this experiment was 1000 ms. An SOA of 1000 ms produced an overall mean RT of 564 ms, as opposed to an overall mean RT 571 ms at an SOA of 500 ms, and an overall mean RT of 639 ms at an SOA of 100 ms. Pairwise comparisons revealed a significant difference between an SOA of 100 vs. 500 ms ($p=0.001$) and between 100 vs. 1000 ms ($p=0.003$); but a non significant difference between 500 ms and 1000 ms.

The ANOVA produced a significant Box frame main effect ($F(3, 21)= 15.875$, $p<0.0001$). Participants were fastest to respond 'In/Out' to targets appearing in the Bothout situation (536 ms), next fastest in the Bothin condition (548 ms), next fastest in TP:Out, OP:In condition (633 ms), and slowest in the TP:In, OP:Out condition (649 ms).

Taking conditions Bothin and Bothout together, it appears that participants respond 'out' faster than they respond 'in'. Comparing conditions TP:In, OP:Out and TP:Out, OP:In, that is conditions with identical box sizes, participants were also faster to respond 'out' than 'in'. Paired comparisons showed significant differences between Bothin and TP:In, OP:Out ($p=0.021$), between TP:In, OP:Out and Bothout ($p=0.007$); and between TP:Out, OP:In and Bothout ($p=0.008$). The remaining comparisons were not significant (i.e. Bothin vs. TP:Out, OP:In; Bothin vs. Bothout; and TP:In, OP:Out vs. TP:Out, OP:In).

It appears that as target eccentricity increased, so RT increased. The overall RT means for Near targets was 587 ms and for Far targets this was 595 ms. However, there was a non-significant main effect of the target eccentricity manipulation ($F(1, 7) =0.894$, $p=0.3759$).

2-way Interactions:

There were four significant 2-way interactions between the following factors:

(i) Box frame and SOA (F (6, 42) = 10.637, p=0.0001).

As shown in Figure 5.4, a reduction of RTs with SOA was found when the target position was Inside the largest type of box frame, or Outside the smallest box frame (i.e. in conditions Bothin and Bothout respectively). When the target position was in the intermediate size of box frame (i.e. in conditions TP:In, OP:Out and TP:Out, OP:In) RTs did not decrease substantially with SOA.

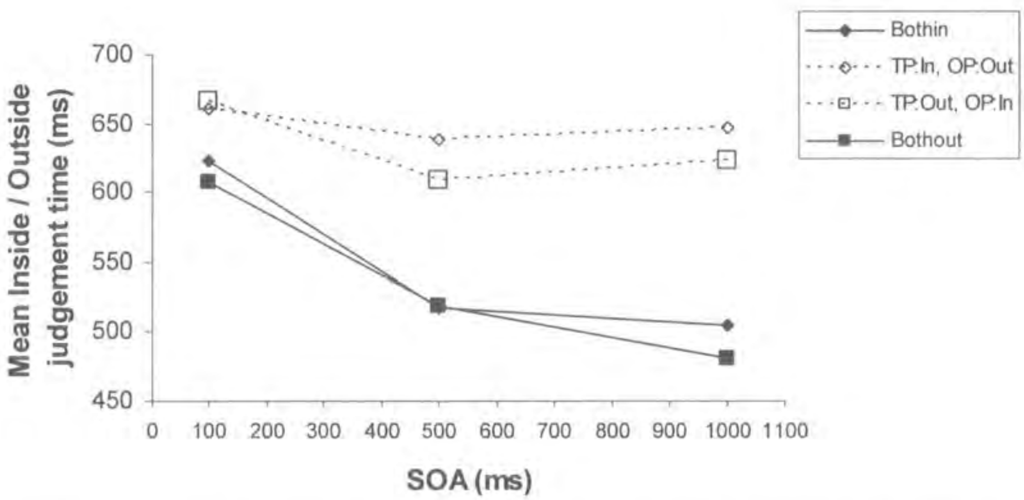


Figure 5.4 Mean Inside/Outside judgement times (ms) for each of the four Box Frames at three SOAs

(ii) Box frame and Target eccentricity (F (3, 21) = 11.060, p=0.0001)

When the target position was 'In' (i.e. in conditions Bothin, and TP:In, OP:Out) RTs increased with increasing target eccentricity. However, when the target position was 'Out" (i.e. in conditions TP:Out, OP:In and Bothout) RTs decreased with increasing eccentricity. (See Figure 5.5.)

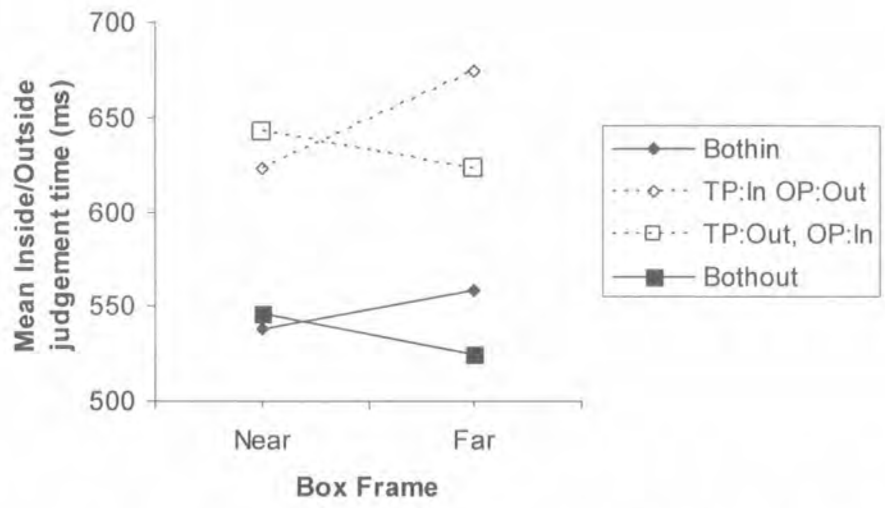


Figure 5.5 Mean Inside/Outside judgement times (ms) for each of the four Box Frames at two target eccentricities

(iii) Cue validity and SOA (F (4, 28) = 5.994, p=0.0013). Decision response times decreased for Valid, Neutral, and Invalid trials with increasing SOA, but by differing amounts; especially from 100 to 500 ms SOAs. (See Figure 5.6.)

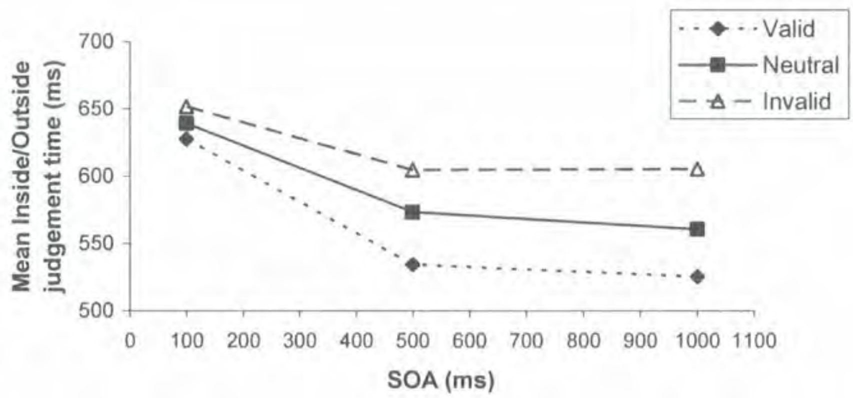


Figure 5.6 Mean Inside/Outside judgement times (ms) for Valid, Neutral, and Invalid trials at three SOAs.

(iv) Cue validity and Target eccentricity (F (2, 14) = 6.501, p=0.0101).

Valid and Neutral decision times increased with increasing eccentricity, whereas Invalid trial times decreased with eccentricity. (See Figure 5.7.)

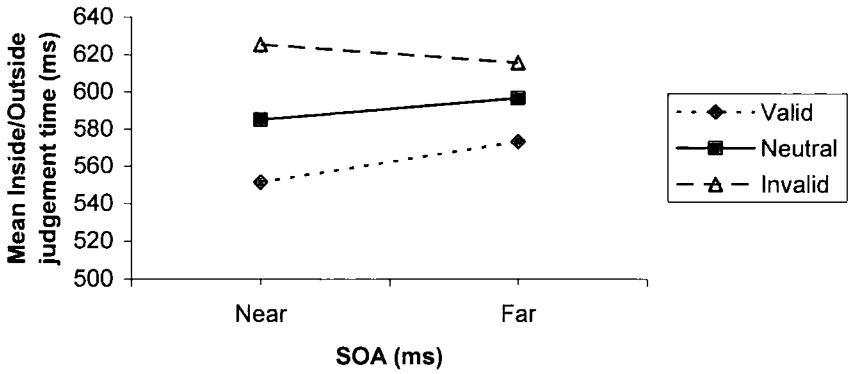


Figure 5.7 Mean Inside/Outside judgement times (ms) for Valid, Neutral, and Invalid trials to Near and Far targets

The two remaining 2-way interactions were not significant:

(v) Box frame and Cue validity (F (6, 42) = 1.679, p=0.1501).

The four box frame conditions were not differentially affected by Cue Validity. (See Figure 5.8.)

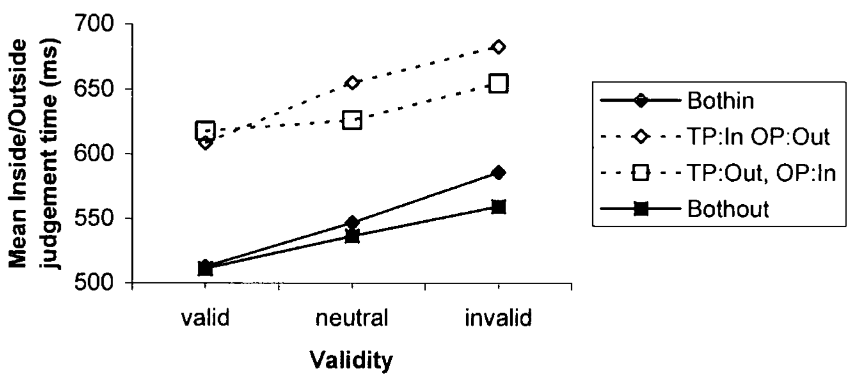


Figure 5.8 Mean Inside/Outside judgement times (ms) for Valid, Neutral, and Invalid trials for each of the four Box Frame conditions

(vi) SOA and Target eccentricity (F (2, 14) = 0.850, p=0.4485).

Figure 5.9 shows that inside /outside judgement times to Near and Far targets vary systematically with SOA.

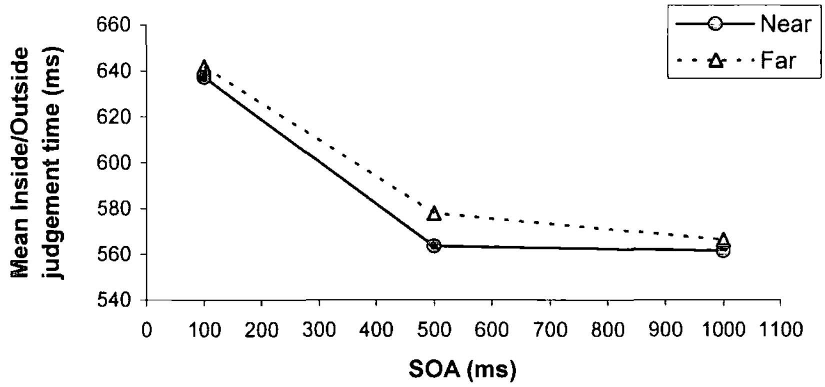


Figure 5.9 Mean Inside/Outside judgement times (ms) for Near and Far targets at each of three SOAs

<u>3-way Interactions:</u>

Two 3-way interactions produced significant results:

(i) Box frame x Cue validity x SOA (F (12, 84) = 2.420, p=0.0095).

The diagrams below (See Figure 5.10) show that the way that Cue Validity and SOA interact varies with the Box frame type. Generally times decrease with increasing SOA, but, for example, Invalid trials for TP:In, OP:Out increase from 500 to 1000 ms SOA, whereas Invalid trials for Bothout decrease over these times.

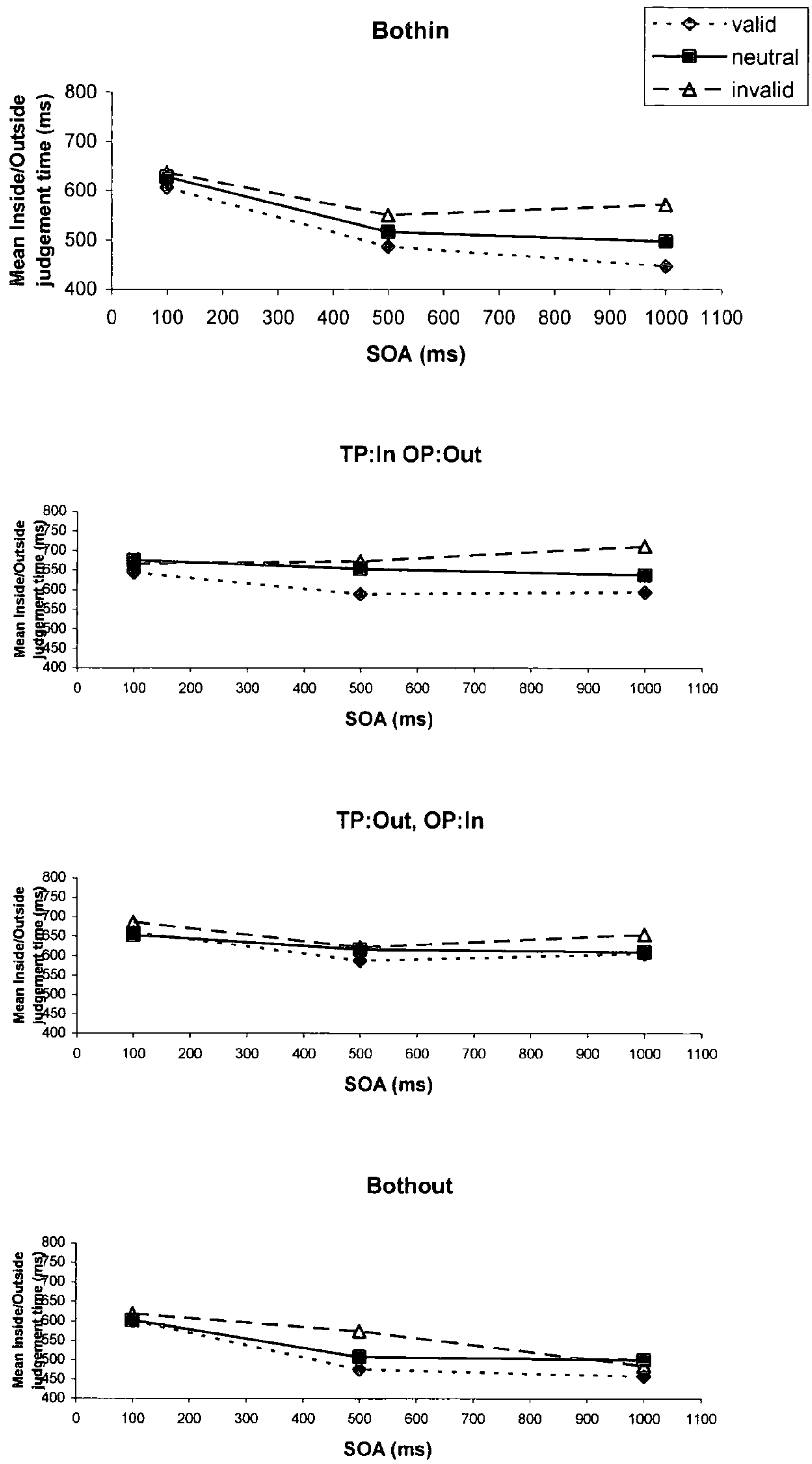


Figure 5.10 Mean Inside/Outside judgement times (ms) for Valid, Neutral, and Invalid trials at each of three SOAs for each of the four Box Frames

(ii) The interaction between Box frame, Cue validity, and Target eccentricity was also significant ($F(6, 42) = 4.118$, $p=0.0024$).

The diagrams below (see Figure 5.11) show that the effects of Eccentricity and Validity interact differently depending on the type of box frame. In general when the target was Outside the Box frame (i.e. in Bothout and TP:Out, OP:In) judgement times for Near targets were slower than for Far targets; the reverse was true for targets occurring Inside the Box frame (i.e. Bothin and TP:In, OP:Out.) Neutral and Valid trials were not as affected by eccentricity: times increase a little from Near to Far for Bothin and TP:In, OP:Out frames, but are very similar for Bothin and TP:In, OP:Out frame types.

The remaining two 3-way interactions yielded non-significant findings:

Box frame x SOA x Target eccentricity ($F(6, 42) = 1.417$, $p=0.2308$) and Cue validity x SOA x Target eccentricity $F(4, 28) = 1.354$, $p=0.2751$).

<u>4-way Interaction:</u>

The 4-way interaction (Box frame x Cue validity x SOA x Target eccentricity) was also not significant ($F(12, 84) = 1.670$, $p=0.0882$).

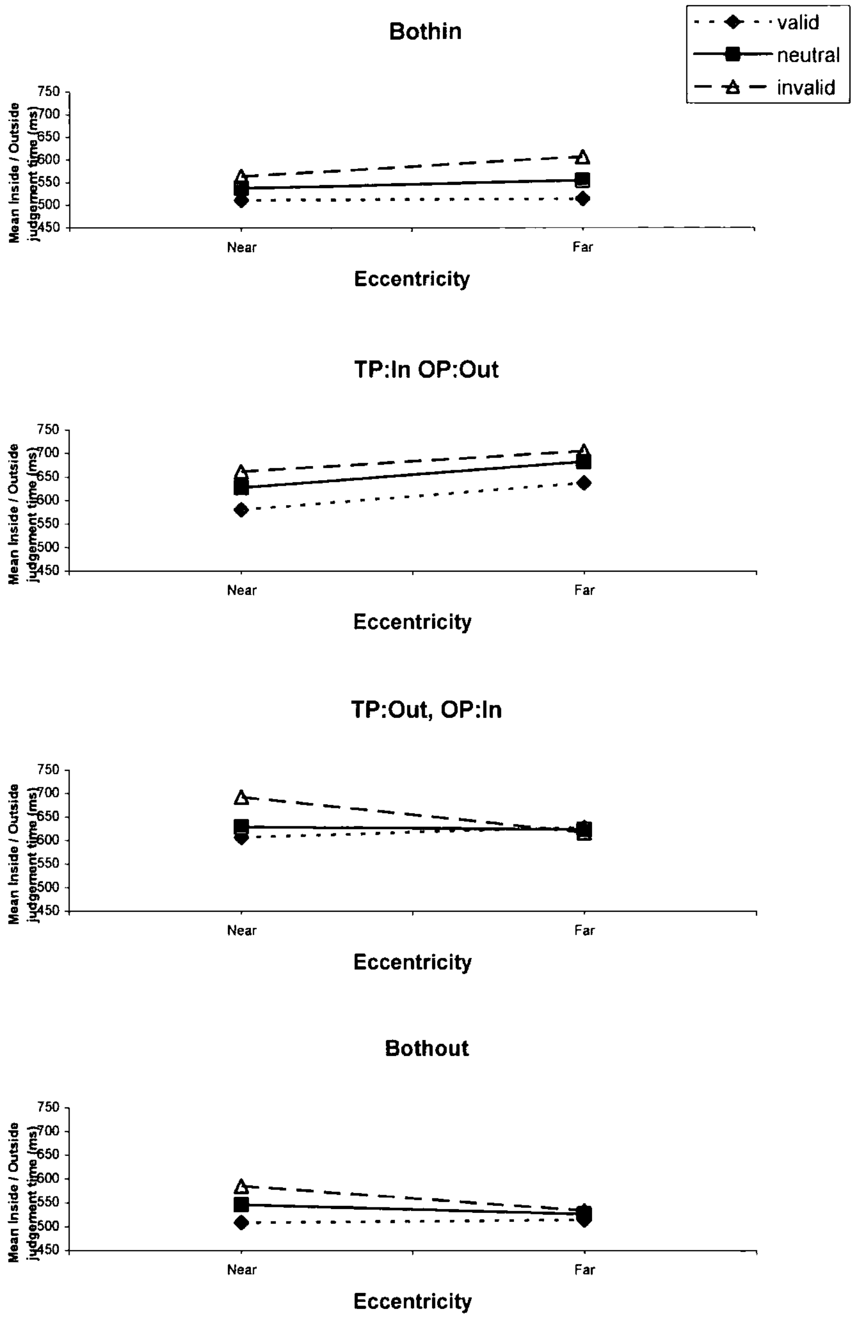


Figure 5.11 Mean Inside/Outside judgement times (ms) for Valid, Neutral, and Invalid trials to Near and Far targets for each of the four Box Frames

5.3.4 Discussion

Accuracy – percentage correct analysis

The overall level of accuracy in this experiment was similar to that found in Experiment 15 (overall mean accuracy was 96%) despite participants reporting 'this was the most difficult experiment I've ever had to do for you!'

The ANOVA for percentage correct scores produced non-significant findings for all but two effects: a Target Eccentricity main effect and a 2-way Box Frame x Target Eccentricity interaction. Therefore, there were similar levels of accuracy throughout, except that, surprisingly, as target eccentricity increased from 8 to 12 degrees, accuracy also significantly increased. This finding was not, however, mirrored by a main effect of Target Eccentricity in the RT analysis.

Decision Time Analysis

Response times overall were generally slower that in the simple detection task (see Experiment 11), but comparable to those found in Experiment 15.

As in earlier experiments, an SOA effect was found, where an increase in SOA produces a reduction in response time.

Similarly, the Cue Validity manipulation showed standard effects: reaction times to Valid trials were fastest, and slowest to Invalid trials.

It was predicted that if this experiment followed the 'dual 2AFC' response pattern of Experiment 15, the fastest to slowest conditions would be as follows: Bothin, Bothout , TP:Out, OP:In , and TP:In, OP:Out. If the experiment followed the 'peripheral' response pattern of Experiment 14, quickest RTs would be found in condition Bothout and slowest in Bothin. The Box Frame results obtained in this experiment produced Bothout, Bothin, TP:Out, OP:In then TP:In, OP:Out from fastest to slowest response times. (Subjective reports also confirm the 'Out' faster than 'In': "Out definitely felt easier than In".) The Bothin / Bouthout ordering was therefore comparable to Experiment 14, and the overall pattern of the four conditions was unlike Experiment 15. Although it should be noted that not all box frames' RTs were significantly different from each other. A replication of Experiment 14 where all four box frame conditions were included into the design would enable fuller comparisons.

Overall, the Benefits of a Valid cue (Overall mean benefit: 29 ms) were larger than those found in Experiment 14 (Overall mean benefit: 18 ms), but smaller than those found in Experiment 15 (Overall mean benefit: 40 ms). The overall Costs in this experiment (mean: 30 ms) were larger than both those found in Experiment 14 (overall mean Costs: 9 ms) and Experiment 15 (Overall mean Costs: 12 ms). It seems that the cue in this peripheral choice decision situation is both a help, but a greater hindrance than in the central 2AFC experiment and in the peripheral detection task.

As mentioned earlier, there was no main effect of Target Eccentricity in the RT analysis, however, there was a 2-way interaction of Eccentricity with Box Frame, and Eccentricity with Cue Validity (and a 3-way interaction with Box Frame x Cue Validity). In general, when the target position was Inside a Box Frame (i.e. in conditions Bothin and TP:In, OP:Out) RTs increased with target eccentricity and when the target position was Outside a Box Frame (i.e. in conditions Bothout and TP:Out, OP:In) RTs decreased with eccentricity, and in particular for Invalid trials. It is difficult to know how to account for this result.

(This was unlike Experiment 14, where there was a main effect of target eccentricity – an increase in eccentricity was accompanied by an increase in RTs.)

In Experiment 14, the two main findings revealed from that analysis were firstly, that Valid Near trials were responded to faster than to Valid Far trials at early SOAs, and secondly, that Invalid trial RTs were faster with Bothout than Bothin conditions, but only for Near targets. The results were interpreted in terms of the visual stimuli and (a possible perceptual grouping) and the resultant interference caused by the position marker and frame distractors.

In this experiment, there was not a comparable finding of Valid Near trials being faster than Valid Far at 100 ms SOA, but this was evident at 500 ms SOA; and this was also true for Neutral trials at and SOA of 500 ms, but not for Invalid trials were RTs decreased with eccentricity. There was some evidence for Invalid trials producing faster responses with Bothin than with Bothout trials, but this was not a significant interaction.

As a result of comments made by Tipper (2005) (see Discussion section to Experiment 15), it was thought worthwhile to include at this point a summary of two additional analyses which further highlight some of the findings already mentioned above.

Table 5.6 shows ANOVA summaries for the overall analysis (shown in full in the Results section of this chapter) in addition to separate combined ANOVAs for Bothin vs Bothout and TP:In, OP:Out vs TP:Out, OP:In box frame conditions. (Differing results are shown in bold lettering.)

Firstly, it is worth noting that only the overall analysis has shown certain significant Box Frame effects (i.e. the Box Frame main effect and the interaction between Box Frame and SOA) – these complex relationships would clearly have been missed in the separate analyses.

Table 5.6 Summary of Experiment 16 combined analysis (i.e. all four box frame typed included), and separate analyses of two box frame condition groupings.

	4 Box Frame conditions analysed together	Bothin vs Bothout	TP:In, OP:Out vs TP:Out, OP: In
Main effects:			
Box Frame	**sig**	**ns**	**ns**
Cue Validity	sig	sig	sig
SOA	sig	sig	sig
Target eccentricity (E)	ns	ns	ns
Interactions:			
Box Frame x Cue Validity	ns	ns	ns
Box Frame x SOA	**sig**	**ns**	**ns**
Cue Validity x SOA	sig	sig	sig
Box Frame x E	sig	sig	sig
Cue Validity x E	**sig**	**ns**	**sig**
SOA x E	**ns**	**ns**	**sig**
Box Frame x Cue Validity x SOA	sig	sig	sig
Box Frame x Cue Validity x E	**sig**	**ns**	**sig**
Box Frame x SOA x E	ns	ns	ns
Cue Validity x SOA x E	ns	ns	ns
Box Frame x Cue Validity x SOA x E	**ns**	**sig**	**ns**

The other main feature highlighted by the table is that of significant findings in the TP:In, OP:Out and TP:Out, OP:In analysis that were not present in the Bothin and Bothout analysis: the 2-way interaction between Cue Validity and Target eccentricity; the 3-way interaction between Box Frame, Cue Validity, and Target eccentricity and, in particular, the interaction between SOA and Target eccentricity, which was not significant in the overall ANOVA). These findings seem to indicate that these two box frame conditions have a more complicated relationship with Target eccentricity than Bothin and Bothout. (Although it would be inaccurate to rule out eccentricity influences on these conditions since, for example, the table shows a significant 2-way interaction of Box Frame and Target eccentricity, as well as a 4-way interaction, for the combined analysis for these conditions.)

To conclude: overall, although with such a complex design it is difficult to tease effects apart, it does appear that the pattern of responding was more akin to that of Experiment 14 than to that of Experiment 15. As well as the usual effects of SOA and Validity, there were clear effects of the box frame and some rather mixed effects of target eccentricity. So, again it appears that the different task led to different results, although the effects of moving the stimuli to the periphery appeared to be the overriding factor, but again giving some indication of some sort of grouping of the stimuli impacting on attentional processing.

Chapter 6
General Discussion

The aim of this thesis was to investigate some of the factors involved in the representation, focus, and movement of attention in visual space. The first part of this discussion will review the experiments and related results presented in Chapters 2-5. The second part returns to some of the attentional themes brought out by the experiments.

6.1 Summary of Experiments in Chapter 2

Chapter 2 presented three pairs of exogenous cueing experiments using LEDs. The cues were the same (Experiments 1 and 2) or spatially distinct from (Experiments 3-6) targets, and were either informative (71% occurring on the Same side as the cue) or uninformative (50% Same side) about the location of a subsequent target. The aim of these experiments was to replicate previous exogenous cueing studies, to investigate the effects of changing the stimulus properties and the cue-target probabilities, and to generate a methodology that might be used in later work.

Experiment 1 used three LEDs, one a centred fixation point and two others positioned 8^0 to the left and to the right. The onset of one of these peripheral LEDs acted as a cue to the target which could occur on the Same side (in fact in this case the same LED) or on the Opposite side to the cue. However, the cue was spatially uninformative: 50% of targets occurred on the Same side as the cue and 50% on the Opposite side to the cue. A broad range of SOAs was used to capture any effects and it was found that, in line with most cueing studies, as SOA increased RT to targets generally decreased. However, unlike previous work there were no facilitatory attentional effects of this spatially uninformative luminance change for RTs to the cued side; only an increase of RTs to the cued side (or perhaps a decrease of RTs to the Opposite side – it was impossible to distinguish between these two possibilities since there was no 'neutral' form of cueing used here).

When the cue and target were in opposite locations, the task was relatively easy, however, when they were in the same location, the discrimination of cue from target was more difficult, especially if participants lost track of the temporal ordering of stimulus events. A possible explanation lies in the relatively blank display used since some previous studies have indicated that no attentional effects are found in such situations.

Experiment 2 used the same display as Experiment 1 but altered the cue-target probabilities. The aim here was to see whether such a change might affect participants' responding despite the fact that they were not made explicitly aware of these contingencies. Although the same problems of discriminability of targets on the Same side were encountered, the results obtained were different from those in Experiment 1: RTs to Same side targets were faster than those to Opposite side target. Despite the fact that this finding did not reach significance, the implication is that the alteration of cue-target expectancies has resulted in some change of responding. Whether this was as a consequence of some internal goal-directed control, or an interplay between this and stimulus-driven control, or for some other reason, is not clear.

Experiment 3 used five LEDs: a centred fixation point, two LEDs at 8^0 to the right and left acted as cues, and two LEDs at 16^0 to the right and left were the targets to which participants were asked to respond. As in Experiment 1, the cues were spatially unpredictive with targets occurring on the Same side as the cue 50% of the time. Since the targets were different LEDs, no problems of discrimination were reported. The results showed a general facilitation at all SOAs: Same side targets were responded to more speedily than Opposite side targets, but this did not reach significance.

Overall the mean times in this experiment, where targets were at 16^0, were shorter than those found in Experiments 1 and 2, where targets were at 8^0. The results do not lend support to the notion that attention moves at a constant rate across the visual field. (It could of course move at a variable rate: faster to further targets.)

Experiment 4 used the same display as in Experiment 3, except that the cue-target probabilities were altered so that targets occurred on the Same side as the cue approximately 71% of the time. The results indicated significant facilitatory effects of the cue, but no inhibition. Overall the mean times in this experiment were again shorter than those found in Experiments 1 and 2 providing more evidence against an analogue description of movement of attention. The mean time for Same side target responding decreased from Experiment 3 to 4, but the RTs to Opposite targets increased. The suggestion here is that this is a consequence of the change in cue-target contingencies which has altered the attentional goal-directed settings.

Since the initial experiments had not yielded the standard findings of facilitation and inhibition, Experiment 5 attempted to generate a 'Posner-box' LED display. A centred fixation point and two boxes made up of eight LEDs (four corner LEDs permanently illuminated and four box-side LEDs flashed on as the cue) with a target positioned in the centre of each box at 12^0 to the left and right of fixation, acted as the stimuli. The cues, as in Experiments 1 and 3, were on the Same side as the target 50% of the time and on the Opposite side to the target 50% of the time. The results showed some facilitation of Same side targets, which surprisingly was at an intermediate SOA, but generally only inhibitory effects were present.

Despite the fact that the target and box LEDs were different colours, participants appeared to have some problems separating the target from its surround which may have explained why these results were similar to those found in Experiment 1. The tentative explanation that the results of Experiment 1 were as a result of a relatively blank screen and a lack of competing targets has not been supported by these findings. There were nine lights constantly illuminated, and other possible distracting stimuli, but nevertheless there was little evidence of facilitatory shifts of attention.

Experiment 6 replicated Experiment 5, except that, as in Experiments 2 and 4, the cue-target contingencies were altered so that Same side targets occurred approximately 71% of the time. The results of the Cue side manipulation were not significant, but showed a trend where RTs to Same side targets were faster than to Opposite side targets. As in Experiments 3 to 4, altering the probabilities of target brought about a decrease in the Same side target RT mean from Experiment 5 to 6, and an increase in the mean RT to Opposite targets. So, similarly, the possibility here is that implicitly there has been a change is participants' goal-directed attentional settings.

In summary then, the six LED experiments produced a variety of results, none of which reproduced previous exogenous cueing results. All showed standard SOA findings where an increase in cue-target onsets produced a decrease in response times to targets. However, the Cue side manipulation and the Cue side x SOA interaction did not show consistent effects.

Some of the results were undoubtedly due to discrimination problems: In Experiments 1 & 2 cue and target were the same LED in the same location and in Experiments 5 & 6, participants seemed to confuse the marker LEDs with the target. This resulted in a similar patterning of the data.

When the cue was spatially, as opposed to temporally, uninformative (i.e. in experiments 1 and 5, where the probability of a target occurring on the same side as the cue was 50%) participants took longer to respond to Same side targets than to Opposite side targets. When the cue was spatially informative (i.e. in

Experiments 2 & 6 where the probability of a target occurring on the same side as the cue was approx 71%) participants tended to respond more quickly to Same side targets, but the results did not reach significance in either of these two experiments.

A plausible explanation for this finding is that increasing the cue informativeness altered the participants attentional control settings. Although they were not explicitly informed of the cue/target contingencies, participants may have implicitly noticed them and altered their behaviour. It is unclear what precise mechanisms would enable participants to do this, but such alterations have been reported in the literature. For example, Folk and his colleagues looking at involuntary stimulus-driven capture noted task contingent changes in their measures of attention.

In Experiment 3 & 4 where there were no problems in discriminating cue from target, participants responded faster to targets appearing on the Same side than to targets appearing on the Opposite side to the cue. The cue/target probability manipulation served to enhance the finding (i.e. a non significant finding in Experiment 3 became significant in Experiment 4).

The results from Experiment 4 (since only facilitation of RTs was observed) support the idea that inhibition of return (IOR) may not be based on sensory stimulation. One view of IOR is that attention moves away from the cued location and inhibition is directed at it. If a response is required to a target at the cued location, inhibition has to be overcome with resulting longer RTs. This suggests a mechanism reflecting a bias towards novel stimuli, or a bias against recently attended locations. Another view of IOR (e.g. Berlucchi, Chelazzi, & Tassinari, 2000) suggests that it is not moving and engaging attention that takes up time, but that once attention has moved from the cued location, sensory processing at that location is inhibited and therefore responding to targets will be slower. The results from Experiment 4 seem to contradict this proposal since no inhibition was found.

A different view of IOR relates attention to oculomotor programming. Evidence suggests that if an eye movement is planned, but not necessarily executed, then IOR is observed. In the experiments described here which do not find IOR (i.e. Experiment 4), then perhaps this is due to a resultant lack of activation of the oculomotor system. However, this would seem surprising given that the targets in Experiment 4 were located at 16^0.

Finally, the LED studies led to some interesting findings relating to the movement of attention, IOR and the effects of altering cue-target contingencies. However they also lead to a cautionary note about the impact of stimulus display properties, such as poor discriminability, on the usefulness of results in attentional exogenous cueing studies.

6.2 Summary of Experiments in Chapter 3

In addition to attempting to reproduce previous exogenous cueing findings, Chapter 3 included four experiments that manipulated the size of the attentional focus and the presence or absence of cue-markers: Experiment 7 had a relatively large attentional focus (2.5^0) and cue-markers present throughout; Experiment 8 had a large attentional focus (2.5^0) and cue-markers absent; Experiment 9 had a small attentional focus ($1/3^0$) and cue-markers present throughout; and Experiment 10 had a small attentional focus ($1/3^0$) and cue-markers absent. All four used a non-informative peripheral brightening cue (i.e. 50% chance of a target appearing on cued side) and a simple target detection task. The results were used to aid the design of experiments presented in chapters 4 and 5; also results had implications for components of visual orienting and in particular for IOR.

In the late 70's and early '80s, several researchers (notably Posner and his co-workers) described attention as a spotlight of a specific size that moved in an analogue fashion. Jonides (1981) suggested attention could be evenly distributed across a display or be focused. The former mode of attending would enable parallel processing, whilst the latter mode would produce enhanced processing of attended elements and worsened processing of other elements. Several studies found a reciprocal relationship between size of attentional focus and discrimination accuracy and processing time (e.g. Beck & Ambler, 1973; Egeth, 1977). A different Zoom lens metaphor was developed to incorporate such findings (Eriksen & St.James, 1985; Eriksen & Yeh, 1985) that suggested that as the size of attentional focus varies the efficiency of processing information also varies; as size of focus increases, efficiency of processing decreases. And more recently Castiello & Umiltá (1990) supported the suggestion of a relationship between processing speed and size of attentional focus. However, other accounts do not make this prediction. For example, LaBerge (1983) noted that the size of attentional focus could vary, but did not conclude that processing speeds increased with the narrowing of attention.

If indeed focus is related to processing capabilities then the results of Experiments 9 & 10, in comparison to those of Experiments 7 and 8, would predict that with a narrowing of attentional focus, there should be some resultant improvement of performance.

Jordan and Tipper (1998) (and Leek, Reppa, Tipper, 2003), on the basis of results using dynamic displays (e.g. Tipper, Driver, & Weaver, 1991; Tipper, Weaver, Jerreat, & Burak, 1994) have suggested that inhibition of return (IOR) is made up of 2 components: location-based and object-based, which together add to produce an overall IOR effect. According to this dual component view of IOR, static displays should produce larger amounts of IOR, since static displays will be the sum of object- and location-based IOR, whereas dynamic displays will only elicit object-based IOR. Using similar reasoning, it was proposed that the absence of the cue-marker should produce a smaller amount of inhibition than when the cue-marker is present since in the former case only location-based IOR should be evident.

Combining the two: cue-marker present/absent and large/small attentional focus might predict enhanced processing with smaller focus and smaller levels of IOR with cue-marker absent; so:

Experiment 7 should result in worse performance (than Experiment 9 or Experiment 10) and relatively large IOR (vs Experiment 8);

Experiment 8 should result in worse processing (than Experiment 9 or Experiment 10) and relatively small IOR (vs Experiment 7);

Experiment 9 should result in better processing (than Experiment 7 or Experiment 8 and relatively large IOR (vs Experiment 10) ;

Experiment 10 should result in better processing (than Experiment 7 or Experiment 8) and relatively small IOR (vs Experiment 9).

Experiment 7 presented a three-box display in the central 6 degrees of vision in an attempt to reproduce earlier exogenous cueing results. Despite some stimulus display and procedural alterations (e.g. no central box brightening), the data broadly produced those expected, showing a speeding of RTs to targets appearing on the Same side as the cue relative to targets appearing on the Opposite side to the cue (a facilitatory effect of 17.9 ms at an SOA of 100 ms) followed by a slowing of RTs at longer SOAs (an inhibition of 18.5 ms). These were slightly reduced effect sizes in comparison to those found, for example, by Posner and Cohen (1984) but these may probably be accounted for by the changes in stimulus properties used in this experiment.

Experiment 8 used a similar display to that used in Experiment 7, except that the cue-markers (boxes to the left and right of fixation) were not permanently illuminated – they were only visible for the duration of the cue.

With the cue-markers absent, the amount of facilitation was reduced to 5.1 ms at an SOA of 100 ms and the level of inhibition increased from Experiment 7 (from 18.5 ms to 39.9 ms at an SOA of 500 ms). The absence of the cue-marker seems to have brought about a reduction in the effectiveness of the cue in terms of speeding detection at short SOAs. Perhaps the lack of these placeholder or landmarks has reduced participants' ability to direct attention in these two-dimensional displays. (Hoffman & Mueller (1994) comment of the failure to direct attention in 3D displays in the absence of placeholder objects.)

The change in the level of inhibition is not consistent with the dual component view of IOR. According to this view, resultant IOR is a combination of object-based and location-based inhibition. This experiment omitted the cue-marker, so that only location based information was available shortly before the target and no object-based information was available. The results should have seen a reduction in the amount of IOR.

Another study which has looked at static displays: McAuliffe, Pratt, O'Donnell (2001) propose a single-component IOR mechanism where objects and locations are treated differently. They predict that maximal IOR will be found when there are only objects or locations in a display, but when both objects and locations are present IOR is more likely to be directed towards objects rather than towards an empty space. Their ideas would also not account for the findings in Experiment 8 since both objects and locations were present and the levels of IOR were greater here than in Experiment 7 when the prediction is that they should either be smaller, or possibly, if IOR is at a maximum, be the same.

One possible reason for not finding the predicted reduction in IOR in this experiment relates to the restricted range of SOAs used. This study only investigated a relatively small range of cue-target onsets since the expectations were that, using exogenous cues, an attentional effect would be found relatively early on in the time-course of events. Perhaps had longer SOAs been investigated the predicted reduction in IOR may have been found. However, the patterning of results did not indicate a downward trend.

Another possible explanation tendered links to the importance, or otherwise of the luminance change in the experiment. Yantis & Hillstrom (1994) have suggested that luminance increments are not necessary to capture visual attention, but that what is important is the appearance of a new object. Cole, Kentridge, and Heywood (2004) confirm this in a change detection paradigm where they show that the visual system is particularly sensitive to the onset of a new object. Although it was supposed that the box flash generated a location-based IOR, perhaps it also created an object-based IOR that summed to an overall greater IOR than that caused by the stimuli in Experiment 7 – since here the luminance increment marked the possible appearance of a new object.

Experiment 9 used a smaller focus of attention and the cue-markers were present. It was predicted that there should be enhanced processing of targets and relatively high levels of IOR. The results did not support the IOR prediction. There appeared to be shorter RTs to targets appearing on the Same side as the cue relative to RTs for target to Opposite side cues, but this was a non-significant effect, and nor was the interaction between SOA and Cue side significant.

As in Experiments 1, 2, 5, and 6, participants involved in this experiment complained of problems of discriminating the cue and target. They were unable to narrow their focus sufficiently to be able to easily distinguish between the cue box and the target cross. This was indicated by the fact that instead of being speeded, the RTs found in this experiment were generally slowed relative to those in Experiment 7.

Again, the limitations of SOA range may have impacted on the findings. If this experiment is viewed more as a discrimination, rather than a detection, task, then previous findings (e.g. Lupiáñez, Milán, Tornay, Madrid, Tudela, 1997;

Lupiáñez, Milliken, Solano, Weaver, & Tipper, 2001) have suggested that the time course of IOR is slowed and looking at longer SOAs may demonstrate an IOR effect.

The final experiment of Chapter 3, Experiment 10, had participants using a narrowed focus of attention with the cue-markers being absent. The prediction was that according to a zoom lens view, in comparison to Experiments 7 and 8, there would be an increased level of performance; and according to the dual component IOR view, in comparison to Experiment 9, there would be a reduced amount of inhibition. However, this was not the case. The results of this experiment showed no facilitation of responding: Same side targets were responded to more slowly than Opposite side targets showing an increased level of inhibition in comparison to Experiment 9.

To summarize the experiments of Chapter 3: the size of attentional focus and the presence or absence of cue-markers was manipulated in an attempt to show evidence of changes of levels of performance and amounts of IOR that would support Tipper et al.'s dual component view.

All four experiments showed clear effects of the SOA manipulation: as the time between the cue and target onsets increased, response times to targets decreased, despite the fact that the cue was spatially uninformative.

Changing the size of attentional focus did not appear to produce any clear-cut consistent effects. The main problem with this aspect of the experimental manipulations was one of discriminability. Participants complained that the targets in Experiments 9 were difficult to detect. Previous studies have indicated that discrimination studies may only show inhibitory effects at SOAs longer than those included here. Extending the range of SOAs, as well as the range of cue-box sizes used, may help to clarify any effects resulting from changes in attentional focus.

According to Tipper's dual component view of IOR removing the cue-marker should elicit a reduction in the amount of inhibition produced. Experiments 8 and 10 both showed increased, rather than decreased amount of IOR relative to Experiments 7 and 9. Thus they did not support the dual component view, nor indeed the single component view described earlier. However, the methodological procedures used in these experiments may not have provided enough evidence to reject either view. Again, the restricted range of SOAs, although initially thought to be suitable, should be extended to incorporate longer SOAs which would afford greater possibilities for supporting or rejecting the dual or single components IOR views. The cue-marker absent technique was designed to generate only a location-based inhibition effect. However, perhaps this particular form of exogenous cueing also generated a new, fleeting, object on the screen which would have caused an increased level of inhibition. Changing the form of this static display, or the form of exogenous cueing (e.g. not generating a new object as part of the exogenous cueing) would again provide further insight into the inhibitory component of visual attention.

Finally, the size of attentional focus and the presence or absence of cue-markers manipulations could have been incorporated into a single experiment. This would have made for a slightly more realistic assessment of the two highlighted issues and, indeed, of everyday attentional orienting, where visual stimuli are constantly changing, rather than held constant.

6.3 Summary of Experiments in Chapter 4

Chapter 4 described four experiments using endogenous cuing of targets in central and peripheral locations in an attempt to demonstrate object-based forms of attentional representation.

Numerous experiments have demonstrated that attention can be allocated to locations or objects in visual space. The growing view is that both forms of attentional representation, space-based and object-based, may coexist, but that the nature of the coexistence remains unclear. This has lead researchers to search for the possible mediators which may distinguish between the two forms. One such mediator is the mode of attentional cueing: exogenous or endogenous. Generally, studies employing endogenous cueing techniques have resulted in space-based forms of attentional representation, whereas exogenous cueing has more often resulted in object-based attention. The majority of work using static displays has used divided visual attention tasks where the location of features of stimuli is investigated in relation to the spatial grouping or object structure of the display. Only a very few studies have successfully managed to demonstrate object-based representations specifically using endogenous cueing and all of these have used very similar techniques to each other. The experiments in Chapters 4 and 5 used a Posner-style detection task in an attempt to demonstrate object-based forms of representation using endogenous cueing.

Experiment 11 used four different styles of box frame presented in the central six degrees of the participant's visual field. The participant's task was one of simple detection of a target occurring either within the confines of the box frame, or outside of the frame. There were two possible target locations and both positions were manipulated with respect to the box frame. (Previous work has mainly concentrated on target and non-target locations all being within an encompassed space or located on an object.) It was hypothesized that if visual attention operates on visually grouped stimuli, and the box frames defined such a grouping, then being inside or outside of the frame would have an impact on the detection time measure. A more extended range of SOAs was used here in the hope of capturing the effects of endogenous cueing since it is well known that the time course of such experiments if usually more extended than those of exogenous cueing. Additionally, previous experiments had been criticized on the basis of using a poor range of cue-target onset intervals. And finally, a randomized design was consistently used throughout the experiments in Chapters 4 and 5, so that the four types of box frame were intermingled throughout the blocks of trials.

The results of Experiment 11 showed the effects of the endogenous cue (i.e. there were significant SOA, and SOA x Validity interactions) but apparently no effects of the box frame manipulation. It appeared that being inside or outside of an object (the box) was not something that was used by the participants in this experiment. It was perfectly possible that people perceived the stimuli as a group, and indeed subjective reports seemed to indicate that they did, however, this grouping was not used in an attentional representation. Vecera and Farah (1994) noted that participants will not encode stimuli in terms of relatively high-level object-centred representations if detection can be accomplished using relatively low-level array representations. It was suggested that had a blocked design been used, participants may have changed the way in which they developed an attentional representation since the task demands would have benefited a representation that incorporated the box frame-object. However, it remains possible, that with the presence of the target position markers, such a strategy would have remained unnecessary.

Experiment 12 was designed as a comparison 'control' for Experiment 11 and later experiments. If a box frame effect had been found, it could have been argued that the results were not as a result of participants generating an object representation, but rather, as a consequence of the visual information adjacent to the target and non-target locations. If there had been a frame effect, similar results may have accrued as a consequence of some boundary crossing effect. In Experiment 12 therefore, the horizontal parts of the box frame were removed. The results of the endogenous cueing detection task here showed the usual SOA and Validity findings, but again, no effect of the 'line frames'. Had there been a significant effect of the frame manipulation, this would indeed have been a problematic result.

Previous studies have suggested that the insertion of placeholders or landmarks in a display may affect the outcome of an experimental manipulation. Additionally, as mentioned earlier, it was possible that given the inclusion of the target position markers in Experiments 11 and 12, it was unnecessary for participants to produce a representation of the visual display that included the box frames - all the information relevant to target detection was available from the central symbolic cue and the two small markers which were present throughout each trial until one (or none, on a catch trial) was occluded by a target. Experiment 13 attempted to deal with the issue. The same stimuli were used as in Experiment 11, except that the two small target position markers were excluded.

The results of previous work have suggested that landmarks may aid detection of targets and indeed this was the case in Experiment 13: overall response times were slightly slower than in Experiment 11. However, the Benefits were larger than those in Experiment 11, but comparable to earlier studies using endogenous cueing (e.g. Posner, Nissen & Ogden, 1978). The Costs were smaller relative to both Experiment 11 and earlier work.

The interesting, but unexplainable finding was the effect of the box frame manipulation. It was predicted that being grouped within a box frame would be of benefit and being outside of such a group would be detrimental. However, the response time data produced a more complicated patterning. The two most unpredictable frames in terms of target responding (i.e. TP:In, OP:Out and TP:Out, OP:In) produced the fastest RTs, followed by the Bothout trial types, then Bothin. (However, it should be noted that not all were significantly different from each other.) So, although there was an effect, it clearly was not a simple one. Looking more closely at the Cue Validity showed that Valid trials were comparable across the four box frame types, but that differences appeared between them with Neutral, but particularly with Invalid trials. Attempts to explain these results in terms of predictability of targets or of the other/non-target position in relation to the box frame, or in terms of the focus of attention size, both fail. Nevertheless, despite the lack of an unambiguous explanation of the results, it is apparent that the exclusion of the position markers had some effect and brought about at least some consequences of the box frame manipulation.

A further possible explanation for the lack of object-based attention in Experiment 11 is that in this centred location it was not necessary to invoke grouped representations. Although there is some disagreement about whether object-based attention does depend on the level of focusing or spatial extent of attention, it was nevertheless thought appropriate to attempt to run at least a partial replication of Experiment 11 placing the stimuli in more peripheral locations. For reasons of economy, only two of the box frames were used in Experiment 14: Bothin and Bothout (i.e. where both the target and non-target positions were both inside the box frame and where both the target and non-target positions were both outside the box frame respectively). These were doubled up on each trial such that there were now four possible target positions, either all four occurring inside a frame, or all four occurring outside of a box frame. Despite the results from Experiment 13, it was predicted that there would be differences between the RTs resulting from the two frames and in addition that if a simple gradient of attentional distribution operates then there would be greater Costs and Benefits for Near than for Far targets.

The results indicated significant differences between the two types of frame used. However, the times to detect targets in the Bothout condition were faster than those to detect target occurring within a frame (i.e. Bothin condition). Looking at overall Costs and Benefits, the Benefits were larger for Bothout trials than for Bothin and also greater for Near than for Far targets; as might be predicted by some spatial gradient models of attention. The patterning of results for Costs was somewhat different: for Bothin there were larger Costs for Near than for Far targets, but for Bothout there were smaller (in fact negative) Costs for Near than for Far targets. This latter result does not fit with a simple spatial gradient viewpoint.

Two main outcomes were drawn out: the impact of the Validity and box frame manipulation appeared to lie with the Invalid trials. Participants were slower to respond to trials occurring on the uncued side if they fell within a box frame than if they lay outside of the box frame. And secondly, the effects of Eccentricity with Validity and SOA indicated that Valid Near targets were responded to faster than Valid Far targets, but mainly at the earlier SOAs. An attempt to describe the processing events was made, but it was not possible to conclusively decide that the results were a consequence of object-based attention. However, given the experiment did yield differences due to the box frame manipulation, it is possible that they could be accounted for by at least some form of perceptual grouping.

To summarize the experiments in Chapter 4: All four experiments showed similar significant effects due to SOA and Validity, as well as significant interaction between these two factors indicating that the endogenous cueing did have an impact using this methodology. The results from Experiments 11 and 12 showed almost identical results. They appeared to show, despite subjective reports, that there was no effect of the box frame manipulation nor an interaction with other factors. This rather depressing result appeared to indicate that it was not possible to produce object-based grouping using endogenous cues, a detection task, and this particular stimulus display. However, such findings could have been accounted for by the unblocked, randomized procedure employed, by the effects of the target position markers, by the central positioning of the stimuli and by the strategic control of participants making it unnecessary for them to encode the stimuli as objects, or perhaps to invoke an object-based, or spatially-grouped array.

Experiment 13 removed the target position markers in the display producing an unexpected and puzzling, but significant effect of the box frame. It was not possible to explain the results in terms of target predictability or attentional focusing, but nevertheless they do indicate a possibility that some form of grouping took place.

The final experiment in this chapter moved the stimuli into a more peripheral location. The pattern of Costs and Benefits varied with the type of box frame again indicating a possibility of grouped attentional representation.

6.4 Summary of Experiments in Chapter 5

In attempting to explain the results of Experiment 11, it was proposed that participants may not choose to group stimuli if it is unnecessary for them to do so. Evidence from studies on attentional capture has highlighted the importance of looking at both stimulus-driven and goal-directed aspects of experiments. And neuropsychological evidence suggests that there may be different pathways responsible for analyzing what and where an object is; or for analyzing 'what' and 'how'. It seemed plausible therefore that changing the task demands may bring about a concomitant change in attentional representation.

The two experiments in Chapter 5 altered the required response from a simple detection to one of a forced-choice (2AFC). The first experiment presented stimuli in the central area of vision, and the second experiment moved the box frames into the periphery.

Experiment 15 replicated the stimuli and procedure of Experiment 11 except that participants were required to judge whether the target appeared inside or outside of the box frames. If the boxes are perceived as an object and being part of the object is beneficial, then Bothin trials should produce the fastest responding with greatest Benefits and smallest Costs; Bothout trials should produce smallest Benefits and greatest Costs. TP:In, OP:Out might be expected to produce greater Benefits and smaller Costs than TP:Out, OP:In, although it was unclear whether these would be larger or smaller than those produced by Bothout. An alternative prediction based on distraction studies might predict that Bothout and TP:Out, OP:In would benefit the decision making process since they have targets occurring outside of the grouping causing less interference than Bothin and TP:In, OP:Out trials.

The results showed that generally participants were very accurate in their responding. The RT analyses showed generally slower responding than, for example, in Experiment 11 – unsurprising since this was a 2AFC task. Overall the Benefits for Bothin, TP:In, OP:Out, and TP:Out, OP:In frame types were all increased relative to Experiment 11, whereas Benefits for Bothout were reduced; the Costs generally decreased for the three former box frames and increased drastically for the Bothout condition. The size of attentional focus cannot account for the findings, not can an explanation based on distractors in the display. The description that best (though not entirely) fits the data is one where the experimental box frame stimuli are perceived as a group and that being contained within the group benefits inside/outside judgments.

Experiment 16 drew together two earlier experiments. In Experiment 14 it was found that moving the targets and box frames (though not the central symbolic cue) into the periphery produced an effect of the frames that had not existed when stimuli were presented in the centre of the visual field. In Experiment 15, the task demands were altered so that participants had to judge whether a target was inside or outside of a box. The results again indicated that grouping may have occurred. However, the patterning of results produced by these two experiments differed: in Experiment 14 Bothout response times were faster than Bothin (the other two conditions had been omitted); whereas in Experiment 15, Bothin RTs were faster than Bothout. Would the 'shift to the periphery' or the 'where is the target' strategy prevail, or would a combination of the two task demands interact to produce a different pattern altogether?

The overall level of accuracy was again very high despite the participants' stated difficulties with the task. The RT analyses produced intermediate levels of Benefits (29 ms), that is, greater Benefits than in Experiment 14 (18 ms), but smaller Benefits than Experiment 15 (40 ms). The Costs were much greater here (30 ms) than in Experiment 15 (12 ms) or in Experiment 14 (9 ms).

There was an overall effect of the box frame which produced a pattern of responding which was more similar to that of Experiment 14, than to Experiment 15: RTs to Bothout targets was faster than to Bothin targets. However, due to the complex nature of the experimental design is was extremely difficult to tease apart the various effects, but nevertheless it is clearly apparent that presenting the frames and targets at a greater eccentricity has again shown some grouping of the stimuli, but it is unclear whether this is a result of a truly object-based representation, rather than that of a locationally invariant spatial grouping.

To summarise the main findings from the experiments in Chapter 5: Changing the task demands of an experiment clearly produced significant differences in the effects on attentional orienting. Presenting stimuli in the central region of vision produces a different patterning of results to those found when stimuli are presented more peripherally. It appears that the task demands have altered the representation on which attention operates, but it is unclear whether this is now object-based or another form of grouping.

6.5 Attention themes

(Objects vs space – Inhibition of return – Focus – Movement of attention – Position markers – Goal-driven and stimulus-directed control – Participants in attention studies - Blocked vs randomised design – Overt and covert links)

This next section returns to some of the issues raised in the General Introduction, incorporating the results obtained in this thesis, highlighting some of the problems, and presenting suggestions for further research.

6.5.1 Object- vs space-based representations
(Have I shown object-based effects using endogenous cueing?)

There is a wealth of evidence that supports the idea that visual attention operated in a spatial manner. However, numerous researchers have challenged this view of a unique role for location and proposed that attention can be directed to segmented perceptual objects and perceptual groupings, rather than to unsegmented areas of visual space. It now seems apparent that attention may well be object-based, or space-based or both depending on the specific contexts and tasks of an experiment. Indeed spatial effects have been reinterpreted as object-based effects (see Duncan, 1984) and vice versa (e.g. Tsal & Lavie, 1993). However, the broader theoretical overview is far from clear. This has led to a search for the variables which might constrain the two forms of attention. I decided to look at one possible mediator, that of attentional cueing.

Many studies have now shown object-based effects using exogenous cueing, but only a few have successfully reported such findings using endogenous cueing. These experiments have tended to use very similar techniques (based on the double rectangle experiments of Egly, Driver, & Rafal, 1994). If another methodology could show object-based findings, it would lend support to the idea that there needs to be an integrated mechanism incorporating the space-object and endogenous-exogenous dimensions, rather than a system that views these as independent.

Experiment 11 set out to show endogenous cueing effects. Although there were obvious location-based aspects to the design – the task was a detection of targets, but these were kept to constant locations – and the methodology also involved, as a by-product of the randomised procedure, some exogenous cueing, it was felt that the box-frame conditions introduced here might prove fruitful. If an effect of being inside or outside of a frame was found and effects could not be accounted for on the basis of focus size, or distractor location, then it was argued that an object-based explanation could be invoked.

Although both Experiments 11 and 12 showed effects of SOA and of Validity, they showed no significant effects of the box frame. And despite the fact that subjective reports indicated that participants thought of the different stimuli as boxes/objects on the screen, these simple detection tasks with endogenous cueing showed no evidence of attention operating on object-based representations.

Although there is some disagreement about whether object-based attention does depend on the level of focussing or spatial extent of attention (i.e. distance from fovea) it was thought a possibility that moving the box frame stimuli used in Experiment 11 into the periphery might elicit a different set of results. And indeed it did. However, the predicted Bothin faster than Bothout was not found. In fact the reverse. It was concluded that, despite this finding, since the results in Experiment 14 were significant and different to those found in Experiment 11, then the findings were not as a consequence of focus size, or exogenous cueing, or distraction effects, but that they were an indication of a possible object-based form of attention.

However, another possible explanation relates back to Experiment 12. It was suggested that this be run as a control for Experiment 11 – if frame effects had been found then these might be accounted for by some boundary crossing property of the stimuli. Since some evidence of a frame effect was found in Experiment 14, then this too might not be as a result of the frames being an object or set of grouped stimuli, but as a result of the stimuli near to the target location. In other words, the effects may be due to crossing a line or a boundary, rather than to being part of an object-based representation. Although there were no effects of the line frames found in central vision, it is possible that they might have an impact in peripheral vision. So, a necessary follow-up experiment would be to move the 'line frames' into the more peripheral locations to see if these stimuli produced similar results to those of Experiment 14.

Experiments 13, 15, and 16 also showed effects of the box-frame manipulation, although the nature of results was not consistent across studies. For example, Experiment 14 showed RTs to Bothout targets were significantly faster than to Bothin targets, whereas Experiment 15 showed RTs to Bothin targets were generally faster than those to Bothout, and a different pattern of Costs and Benefits. These differences could be accounted for by the differing task demands, or the move of stimuli to a more peripheral location. The results of Experiment 16, which involved a choice decision task and had targets occurring more peripherally, were more akin to those of Experiment 14 than Experiment 15. So, perhaps the initial wide focus of attention is the factor that dominates over the type of task (i.e. simple detection or 2AFC).

So, to conclude, although the findings were not always clear cut, the different box frames did produce different results which seem to be indicative of a stimulus-grouping effect. Whether I can call this an object-based representation finding is less clear. Perceptual organisation has clearly affected the allocation of attention in these experiments, but, for example, boundary-crossing, or part-object effects might still be possible explanations. Replication and further controls and manipulations of the stimuli might reinforce an object-based effect.

6.5.2 Inhibition of return (IOR)

Tipper and his colleagues (e.g. Leek, Reppa, & Tipper, 2003) proposed that inhibition of return (IOR) consists of two components (location-based and object-based) which should sum to produce a total level of inhibition. McAuliffe, Pratt, and O'Donnell (2001) suggest a single component IOR mechanism where objects and locations are treated differently. In the static display situation, both these explanations would predict a relatively large amount of IOR in Experiments 7 and 9 (since they have the cue-markers present which should produce location-based and object-based IOR) and a relatively small amount of IOR in Experiments 8 and 10 (since the cue markers absent and they only have location based cue flashes). But the absence of the markers seemed to increase the amount of IOR not decrease it. So, these results are not consistent with either the dual component additive view, or the single component view. However, it is possible that the luminance increment of Experiments 8 and 10 may have marked the possible appearance of a new object, and generated an object IOR which would have increased the IOR in the cue-marker absent conditions to a level on a par with the cue-marker present conditions.

There was also a total absence of IOR in Experiment 4 which again is not in keeping with the predictions outlined above. Presumably the LEDs used in the experiment should have produced a location-based IOR and an object-based IOR, but there was no evidence of inhibition whatsoever!

A possible follow-up experiment would be to extend the range of SOAs used since in Experiment 7-10 only a restricted range (100, 300, 500 ms) was used and in Experiments 1-6 SOAs from 150-750 ms were used; despite the fact that exogenous cueing inhibitory effects should be apparent at these time intervals, nevertheless extending the SOA might prove informative. Furthermore a change in the form of the static display, or the form of exogenous cueing, so as not to generate a new object might provide further insight into the inhibitory component of visual attention.

6.5.3 Attentional focus

The size of attentional focus was addressed by a number of studies in the 70's and 80's but has currently become a less popular aspect of attentional research. The majority (although not all) of the results seem to favour a reciprocal relationship between the size of attention focus and processing efficiency.

As outlined in the summary of Chapter 3, Experiments 7-10 manipulated box size in a similar fashion to Umiltá and colleagues (although I incorporated another element into the deign which looked at IOR). The results of my experiments seemed to indicate no attentional focus size effects, or else one that was swamped by discriminability problems. Experiments 7-10 used a different range of SOAs to that used by, for example, Castiello and Umiltá (1990), but the maximum was 500 ms in both. Perhaps the critical differences were the cueing procedures used. For example, in their Experiment 1a, Castiello and Umiltá did not include an Invalid (or Opposite side) condition and flashed sometimes one and sometimes two boxes to indicate valid and neutral trials respectively; in their Experiment 1b, they used solid and dashed line boxes to indicate validity; and finally, in contrast I used a blocked methodology whereas they did not.

Experiment 13 also produced a pattern of results not in line with ideas relating to attentional focus. Goldsmith and Yeari (2003) propose that when attention is diffuse, then object-based attention may be obtained, but that these effects may be reduced when attention is narrowed. In Experiment 13, generally RTs were fastest for condition TP:In, OP:Out which was faster than condition TP:Out, OP:In, then Bothout and finally Bothin where RTs were the longest. The results did infer an object-based style of attention since there was an effect of the frame, but the smallest sized box did not produce the fastest responding; the largest did however produce the worst. So, focus of attention on its own did not account for these findings. It is more likely that there was an interplay between a number of factors including focus and perhaps more top-down forms of control (e.g. participants tried harder with the conditions that were perceived as being more difficult i.e. with TP:In, OP:Out and TP:Out, OP:In) although I have no evidence for this.

The results in Experiment 15 similarly produced results that could not be accounted for by focus-based explanations. Here RTs to targets followed a pattern from fastest to slowest: Bothin, Bothout, TP:Out, OP:In, then TP:In, OP:Out – i.e. largest focus size followed by smallest focus size, followed by the two intermediate sized boxes.

Finally, an explanation based on focus might help account for the finding in Experiment 14. If the focus of attention was initially wide and then narrowly narrowed to the Bothout box frame and widely narrowed to the Bothin box frame, then this would result in RTs to Bothout targets being faster than to Bothin targets. Experiment 14 did not include the other two conditions, so a useful follow-up would be to replicate Experiment 14 including the two 4^0 x 6^0 box frames.

So, in general, the size of attentional focus did not seem to play a great part in explanations of either the exogenous or the endogenous cueing experiments.

6.5.4 Movement of attention

Early work looking at the progress of attention suggested that it moved in a smooth analogue fashion, at perhaps 1^0 per 8 ms. Later research suggested that attention moved in a distance independent fashion perhaps jumping over intervening locations and objects. Was there any evidence to support either of these positions in my experiments?

In Experiments 1 and 2, targets were located at 8^0 to the left and right of fixation, and in Experiments 3 and 4, targets were located at 16^0 to the left and right of fixation. The overall mean RTs in the latter two experiments were shorter than the overall mean RTs in Experiments 1 and 2. These results therefore do not lend support to the notion that attention moves at a constant rate since this would have predicted longer times to the more distant targets. Instead it suggests either that attention moves in leaps, or that it moves at variable rates depending on the distance it needs to travel: here the finding would suggest that attention has moved faster to further targets. However, discrimination problems encountered in Experiments 1 and 2 would be imprudent to make any firm conclusions about the movement of attention based on comparisons between these experiments. The problem of distinguishing between the 'identical' cue and target in Experiments 1 and 2 may have caused an increase in RTs overwhelming any effects caused by having targets at smaller eccentricities than those in Experiment 3.

(Although the participants involved in these experiments did vary and the results could be solely due to between-participant variation.)

Contrary to current opinion and to the results of the LED experiments just mentioned, the results from Experiments 11 and 14 do appear to indicate an analogue style of movement. Experiment 11 had targets at 2^0 to the left and right of fixation and Experiment 14 had targets at 8^0 and 12^0 to the left and right of fixation. In general the RTs in Experiment 14 were longer than those in Experiment 11, but care must be taken when making direct comparisons since stimuli were doubled up in the peripheral locations and also a different set of participants were involved in the two experiments. However, when comparing the two eccentricities in Experiment 14, RTs to near targets (i.e. at 8^0) were significantly faster than RTs to far targets (i.e. at 12^0). However, although on the surface there appears to be an analogue movement of attention, eccentricity in this experiment also interacted significantly with other factors (i.e. 2-way interactions with validity and SOA; 3-way interactions with box frame and validity, and with SOA and validity; and a 4-way interaction) indicating that a straightforward explanation of movement may not suffice here.

There were no simple main effects of eccentricity in Experiment 16. Instead there were several interactions which generally showed that when the target position was inside a box frame (i.e. in conditions Bothin and TP:In, OP:Out) then

RTs increased with target eccentricity; but when the target position was outside the box frame (i.e. in conditions Bothout and TP:Out, OP:In), then RTs decreased with eccentricity. So this does and does not support an analogue movement of attention.

6.5.5 The use of target position markers, landmarks, and placeholders.

Vecera and Farah (1994) reported that if detection can be accomplished using low-level array representations, then it will be, with no need to encode stimuli in terms of objects. The results obtained in Experiments 11 and 12 may be accounted for by the presence of the target position markers, since the task could be accomplished quite easily by focussing solely on these markers with no need to take into account the frames (apart from perhaps as a general alerting cue to the onset of the target)

Only one of the endogenous cueing experiments (Experiment 13) omitted the target position markers. It was felt that since this had produced effects on the RT measure, then it was better to keep this stimulus feature in the remaining experiments, so that results could be compared with those 'baseline null effect' object-based of Experiments 11 and 12. Clearly it would be interesting to investigate the effects of removing these position markers with stimuli presented in the periphery and using judgement tasks. My prediction would be a finding of stronger grouping effects since there would be nothing in the visual field apart from the box frames on which to focus.

Recent studies have investigated the effects of abrupt visual onsets and whether they are sufficient to capture attention and produce object-based representations. Relatively little has been done in the way of specifically investigating these landmark effects, but they seem, at least in detection studies, to be a vital ingredient of the experimental stimulus recipe. Furthermore since Vecera and Farah (1994) seem to indicate that this may be under strategic control of participants, then it might be interesting to vary the saliency of these markers to look at the interaction between goal-directed and stimulus-driven properties.

6.5.6 Goal- directed and stimulus- driven control

Recent work by Folk and his colleagues has highlighted the importance of interactions between goal-directed and stimulus-driven effects. In Experiments 1-6, despite the fact that participants were not explicitly told of the cue predictability, when the cue-target contingencies were changed from 50% probability of cue and target being in the same location to 71% likelihood of the cue predicting the target location, the effects observed in the LED experiments were altered. (I.e. Experiments 1, 3, and 5 used 50% probabilities; Experiments 2, 4, and 6 used 71%/29% probabilities.) Although not all the experiments showed significant findings, nevertheless, a change in the patterning of results was shown for all three stimulus-pairs of experiments. The exogenous cue, despite being an abrupt luminance change and, as such, an extremely salient attention-capturing stimulus previously thought of as not under volitional control, has here had its effects modified presumably by some form of goal-directed modification.

In an entirely different experimental structure, it is apparent that changing the task demands, and presumably the balance between goal-directed and stimulus-driven control, altered performance. Experiments 15 and 16 used an inside/outside judgment task in comparison to the simple detection task used, for example, in Experiment 11. There were clear differences between the results of these experiments which, in the comparison between experiments 11 and 15 can only really be accounted for by the change of task.

6.5.7 Participants in attention studies

The participants involved in the experiments described in this thesis were not controlled in a number of ways which may have had an effect on the outcome of results. It was decided not to try to control for age or experience of participation in attentional studies, since it was felt that findings should be of sufficient strength to be generalisable beyond these limits. Furthermore, relatively small numbers of participants completing numerous trials were used in each experiment, mainly since many of the studies were often extremely long and tedious to complete. However, in retrospect, this lack of control may have been ill-advised.

Participants were usually restricted to undergraduates and postgraduates with ages ranging between 18 – 24 years. However, a number of experiments also used older members of staff. There is now evidence to suggest that attentional effects change with age. Tipper et al (1997), for example, showed that inhibition of return is positively correlated with age. Given these sorts of findings, it would have been better to have kept to a limited age group.

A second factor that should be addressed here is that of experience. Although it was initially felt that experimental naivety was not of importance, it has become apparent that, perhaps particularly when trying to demonstrate object-based effects in static displays, IOR can be a fragile effect. For example, Müller and von Mühlenen (1996) concluded that "dynamic, object-centred IOR is observed only under some special experimental conditions, and only early during (inexperienced) subjects' performance on the task." (p247). Similarly, Weaver et al (1998) and Jordan and Tipper (1999) both demonstrated that inhibitory effects gradually decline with exposure to a task so that generally they are non-significant in the second half of a study. Additionally, the size of IOR effects appears to be adapted by the salience of objects. (See, for example, Vecera and Farah, 1994.) However, on running a cross blocks analysis for Experiments 1-6, no such reduction of effects was apparent (though there were other problems with the design of these experiments). Nevertheless, given the above discussion, it would be unwise to be entirely confident of the replicability of some of the findings in the latter experiments presented in this thesis, and future experiments would be better run using inexperienced participants.

6.5.8 Blocked versus randomised designs

The initial experiments in Chapters 2 and 3 used blocked designs, whereas those in Chapters 4 and 5 were felt to be more 'naturalistic' by having a randomised presentation of the different stimuli. Although I still think it important to include a randomised presentation somewhere in a series of such experiments, the studies described in Chapters 4 and 5, or at least some of them, should be repeated using a blocked design.

Participants, for example, in Experiment 11 may have been induced into using the box frame information, and into generating an object-based representation on which attention operated, to aid their responding. However, with a blocked design the nature of predictability would be more of an issue: Conditions TP:In, OP:Out and TP:Out, OP:In would only have one possible target location that was always inside or always outside the frame respectively. This means that participants could ignore the symbolic cue and use it only as a temporal alert. Conditions Bothin and Bothout would have two possible target positions and the blocked presentation comparison between these two frame types might prove more interesting. Issues of attentional focus size might also prove to be a difficult confound since Bothin is a smaller frame than Bothout. (But the evidence from experiments in Chapter 3 suggests that focus size may not always be important at more central locations.)

Clearly, the nature of the design used has an important role to play in making conclusions about these types of display. (Also see discussion on differences between my experiment and those of Castiello and Umiltá (1990) where blocked methodology may have proved critical.)

6.5.9 Overt and covert links

Although the experiments in this thesis were all concerned with covert orienting there has been much research demonstrating the link between saccadic programming, movement, and attention and it seems appropriate to make at least some comment on the nature of the link between these systems.

According to Findlay and Gilchrist (2003), there are three types of relationship between overt and covert visual orienting: Firstly, the position exemplified by Klein in his 'independence account' is that there is no causal link between saccadic programming and attention (Klein, 1980; Klein & Pontefract, 1994). The two processes occur simultaneously as a result of being driven by the same external visual stimuli. The second position links the two forms of orienting more closely. Henderson (1992) proposed a 'sequential attentional' model where covert orienting necessarily precedes, but can be made without a following, overt movement of the eyes. In the third position there is a close association between covert attention and saccade generation.

This last proposal, the pre-motor theory of attention was espoused by Rizzolatti and colleagues (e.g. Rizzolatti, Riggio, Dascola, & Umilta, 1987; Rizzolatti, Riggio, & Sheliga, 1994; Sheliga, Craighero, Riggio, & Rizzolatti, 1997; Sheliga, Riggio, Craighero, & Rizzolatti, 1995). They suggest that there is no response-independent representation of space being activated by an attention mechanism. Attending involves activating the specific motor programmes that are appropriate to the response system being used. In the case of visual attention this would imply a strong association with the brain mechanisms involved in eye movements. In particular, the pre-motor theory of attention would explain covert attention shifts as being a consequence of the oculomotor system preparing to generate a saccade. If such a theory were true then explanations of attention that did not draw on eye movements might be worthless. Fortunately the evidence from damage to the brain structures relating to saccade generation (e.g. the superior colliculus) suggest that whilst they may be involved in attentional orienting to exogenous cues, they do not seem to be involved in orienting to endogenous cues.

6.6 Conclusions

To conclude, the work presented in this thesis has addressed some of the factors involved in the representation, focus, and movement of covert attention in visual space. Current models of inhibition of return were not supported by the results of exogenous cueing studies, nor was the reciprocal relationship between attentional focus and performance generally confirmed. The majority of experiments did not support a simple analogue movement of attention; an explanation where movement interacts with other variables seems more appropriate. Also, it was evident from a number of results that the stimulus-driven responses clearly interacted with the top-down, goal-directed aspects of the experiments. And finally, some evidence of perceptual grouping was apparent in a number of experiments; although further research would be needed to resolutely conclude that endogenous cues could elicit object-based representations calling for a rethink to the theoretical structure of mechanisms describing the space-object and endogenous-exogenous dimensions.

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